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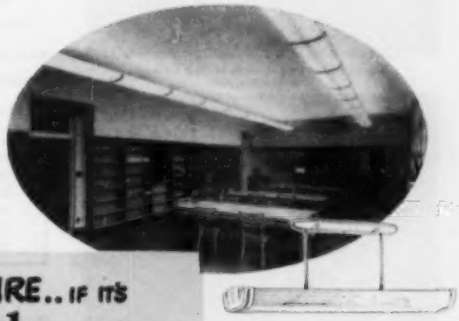

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ILLUMINATING ENGINEERING

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JULY
1952

Vol. XLVII
No. 7

Views and Opinions—The Importance of Lighting in Our Defense Production ... H. L. Harrison 351
Organizing Light for Production ... Arthur A. Brainerd 352
A Study of Eye Complaints from Fluorescent Lighting ... Willard Allphin 357
Comfort with High Levels ... 360
Specifications for Production Lighting ... George J. Taylor 361
Lighting Data Sheet—Series XVII Floodlighting Stocks (24-26) ... 365
Techniques for Exposing the Industrial Saboteur ... Carl F. Jensen 367
Characteristics of Porcelain Enamel As Used in the Lighting Industry ... Eric H. Church 369
Photographing Lighting Installations ... Tom Knowles 375
These Industrial Installations Won Merit Awards ... 379
Design Considerations in Lighting an Industrial Plant ... Harvey R. Judd 384
Oculomotric Muscle Forces and Fatigue ... Kurt S. Lion 388
The Use of the Luckiesh-Moss Visibility Meter for Prescribing Illumination ... Glenn A. Fry 391
The Photometry of Projected Light ... J. M. Waldram 397
Questions and Answers on Light Sources ... 409
Also: High Bay Mercury Units Used in Industrial Area, 374; Portable Fluorescent Lamp, 378; Louvered Lighting in Woodworking Shop, 387; Comfortable Lighting in a Bakery, 390
TELECAST—Lighting News of Current Interest ... 6A
Here and There with I.E.S. Members, 9A; Lighting Calendar, 15A; It Seems to Me, 18A; Books and Pamphlets, 18A; About People, 21A; Obituaries, 21A; New Members, 21A
I.E.S. National Technical Conference ... 11A
I.E.S. Publications ... 35A
Index to Advertisers ... 37A

Committee Personnel, 1951-1952—For latest listing refer to March 1952 issue of ILLUMINATING ENGINEERING.

National and Local Officers, 1951-1952—For latest listing refer to March 1952 issue of ILLUMINATING ENGINEERING.

Sustaining Members—For latest listing refer to May 1952 issue of ILLUMINATING ENGINEERING.

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Founded 1906

ILLUMINATING ENGINEERING SOCIETY

A. D. Hinckley, Executive Secretary
C. L. Crouch, Technical Director

PUBLICATION office 32d Street & Elm Avenue, Baltimore 11, Md.

EDITORIAL and advertising offices 1860 Broadway, New York 23, N. Y.

ILLUMINATING ENGINEERING: The Journal of the Illuminating Engineering Society. Copyright 1952 by the Illuminating Engineering Society. Published monthly in the United States of America. Entered as second-class matter at the Post Office, Baltimore, Md. Acceptance for mailing at special postage rates provided for in Section 1103 P.L.&R., Act of October 3, 1917. Authorized July 16, 1918. ¶ Subscription $10 per year plus extra postage to all countries to which second-class postage rates do not apply; single copies $1.50. † Address changes must be received at I.E.S. headquarters by the first of the month to be effective with the issue of the next succeeding month.

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Views and Opinions

The Importance of Lighting In Our Defense Production

BECAUSE Lighting is not used in combat, its importance as an essential factor in the mobilization of American industry for the National Defense is not fully realized by those responsible for the Defense effort. But the truth of it should be projected far and wide. It is up to the lighting industry to do a much-needed educational job.

TRUE, the great need is for planes, guns, tanks, ammunition and ships. But how far would production of them get without *light?* How could they be produced in the volume and speed of output needed without *adequate light?*

DEBATES in Congress have been confined to the quantities in which to provide them, and how much money to appropriate for them. The Department of Defense and the Armed Services have devoted much thought to the types of planes, guns, tanks, ammunition and ships to be produced. Special agencies are working day and night to expedite their production. And, in the allocation of vital materials, priority has been given to the manufacturers who produce them.

WHERE does the lighting industry figure in all this? Not where it should, in view of the fact that it produces a prime Defense tool —lighting. Lighting of the right type, properly installed, which will enable workers to see without eye-strain, and reduce accidents and errors. Lighting which speeds production and increases output. Lighting — an indispensable factor in America's Defense mobilization.

THE LIGHTING industry stands ready today to play its full part in America's Defense production. Ready, with its experience in World War II production. Then, you remember, it was feared that we would be "too late, with too little." Facts and figures show that *good lighting* had a stimulating effect on our war production, speeding it up to a production that astounded the world.

LIGHTING today is a determining factor in speeding the transition from consumer production to defense production. In those plants, where, during the last war, good overall general illumination was provided — the continuous wireway system of fluorescent lighting, as an example — it is now possible to change from peace-time to defense production without any change in the lighting, while machines and other operating equipment can be changed as desired. When Defense production ceases, this same good lighting will permit changing back to peace-time production without change in the lighting. No matter how many times machines or operating equipment may be changed around — for defense or peacetime production—properly planned overall general lighting does not become obsolete, nor inadequate for production efficiency, thereby making it a two-way investment.

THE PROVEN effectiveness of *good lighting* should be brought home to authorities in charge of Defense production, so that materials necessary for the construction of lighting equipment can be obtained in the quantity required. This of first importance in the Defense mobilization.

THE LIGHTING industry has a job to be done within its own plants, too. Workers on lighting — the men and women who make lighting equipment — don't fully realize the vital importance of Lighting as a Defense tool, any more than do workers who make the important parts, undertaken by subcontractors, that go into planes, tanks, guns and ships. All these workers should be told of the important part they are playing in the National Defense. They should be made conscious of the fact that, without the *good light* provided by the equipment they produce, American Defense production, in the volume and speed of output needed, would be impossible. This will enhance their pride in their work, and make them feel that they belong in the front ranks of the workers for the defense of their country.

YES! The lighting industry has not only a wonderful opportunity — it has a *duty* — to project into the national consciousness the vital importance of *lighting* in the mobilization of American industry for the National Defense.

H. L. Harrison
The Miller Co., Meriden, Conn.

Organizing Light For Production

By ARTHUR A. BRAINERD

ONE OF the outstanding projects of the I.E.S. is that which involves a systematic study of illumination as it influences the visual tasks in industry. Industry had long recognized that illumination had a pronounced influence on the quantity and quality of goods produced in our vast mass-production enterprises. Around 1930 a start was made toward analyzing the lighting needs of individual manufacturing processes. Papers* were presented at I.E.S. Conferences in which projects of this nature were described. Out of these papers a system was developed of approaching the problem of lighting a new industry as a new case. Engineers were sent into the plant to study the manufacturing process and the visibility problems involved. When sufficient information had been secured, the lighting was designed as a system to fit that particular industry.

At about this time, the Industrial and School Lighting Committee, under the chairmanship of Professor Dates, undertook to organize studies of industrial lighting as a definite I.E.S. activity. This represented a radical departure from the common practice of basing recommendations on a uniform general illumination, with only the footcandle levels and uniform spacing and mounting were specified. At the start of this activity the committee was fortunate in having available as background material, the I.E.S. Lighting Data Sheets which were the result of a program instigated by the late J. Carl Fisher in 1929.

The first industry committee to be formed under the new plan was headed by Mr. Edwin D. Tillson, who assumed the task of analyzing the lighting problems in the printing industry. The achievements and the report of this committee represent an unusually high standard of performance which was reflected in the activities of succeeding committees. One outstanding feature of this study was the development of two large-area, low-brightness luminaires, utilizing the silver bowl incandescent lamps. During the period 1935-1940, under the Industrial and School Lighting Committee, eight industry studies were completed as follows:

Printing Industry, E. D. Tillson, Chairman. Published March 1936.

Shoe Manufacturing Industry, Charles Poey, Chairman. Published March 1937.

Lighting in Textile Industry, Grey Goods and Denim, R. A. Palmer, Chairman. Published March 1937.

Candy Manufacturing Industry, Charles Poey, Chairman. Published May 1937.

Intricate Production, Assembly & Inspection Processes, H. M. Sharp, Chairman. Published December 1937.

Silk & Rayon Throwing and Wide Goods Weaving, A. A. Brainerd, Chairman. Published January 1938.

Machining of Small Metal Parts, J. M. Smith, Chairman. Published January 1939.

Lighting of Power Presses, C. C. Munroe, Chairman. Published February 1939.

From 1941-1943, under the Lighting Practice Committee, three industry studies were completed as follows:

Fluid Milk Division of the Dairy Industry, O. A. Hill, Jr., Chairman. Published November 1942.

Dental Offices, E. W. Fowler, Chairman. Published January 1943.

Art Gallery Lighting, A. C. Knudstrup, Chairman. Published January 1945.

From 1943-1946, under the Lighting in the Work World Committee, four industry studies were undertaken but not completed, as follows:

Heavy Iron & Steel Machining and Finishing, G. A. Gardner, Chairman.

Glazing & Inspection of Suede & Polished Kid Leathers, H. P. Kirk, Chairman.

Rubber Industry, R. F. Hartenstein, Chairman.

Needle Trades (Garment Industry), H. E. D'Andrade, Chairman.

In 1947, a new committee entitled "Lighting Study Projects in Industry" was established. The new arrangement resulted in a rapid expansion of the work. Under this committee six reports have been completed and published as follows:

Bakeries—F. J. Vodicka—June 1950.

Canning Industry—Carl O. Martin—January 1950.

Flour Mills—B. R. Bunn—November 1949.

Small Metal Parts—J. M. Smith—October 1949.

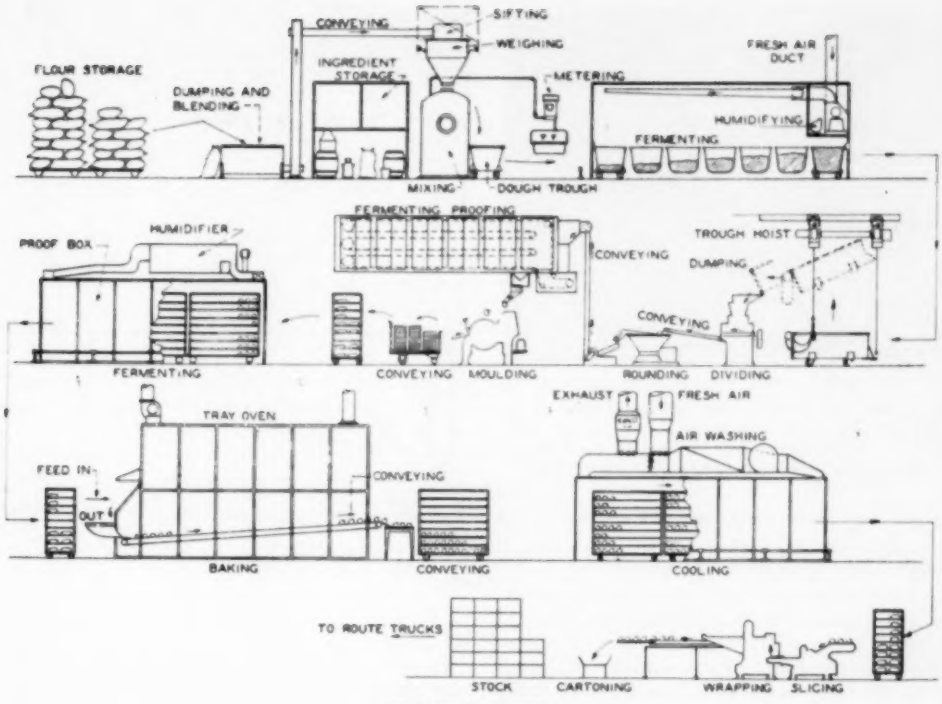
Steel Mills—A. Paulus—(Part I) March 1952.

Textile Industry—W. L. Kelley—(Woolen) June 1949.

There are now in existence, 12 of these study

Author: Chairman, Committee on Lighting Study Projects in Industry, Illuminating Engineering Society.

*Ketch, J. M.: "Lighting for the Inspection of Polished Surfaces," *Trans. I.E.S.*, Vol. XXIII, p. 639 (July 1928).
Luckiesh, M.: "General Lighting Plus," *Trans. I.E.S.*, Vol. XXIV, p. 232 (March 1929).
Ketch, J. M.; Sturrock, Walter and Staley, Karl: "Special Lighting Lighting Applications for Industrial Processes," *Trans. I.E.S.*, Vol. XXVIII, p. 57 (January 1933).
Brainerd, A. A.: "Factory Lighting to Fit the Facts," *Trans. I.E.S.*, Vol. XXX, p. 315 (April 1935).



Lighting for Bakeries

Flow chart for the making of bread.

committees, nine of which are engaged in active work on industry reports. Others are held together to study changes in specific industries which call for modification of lighting recommendations.

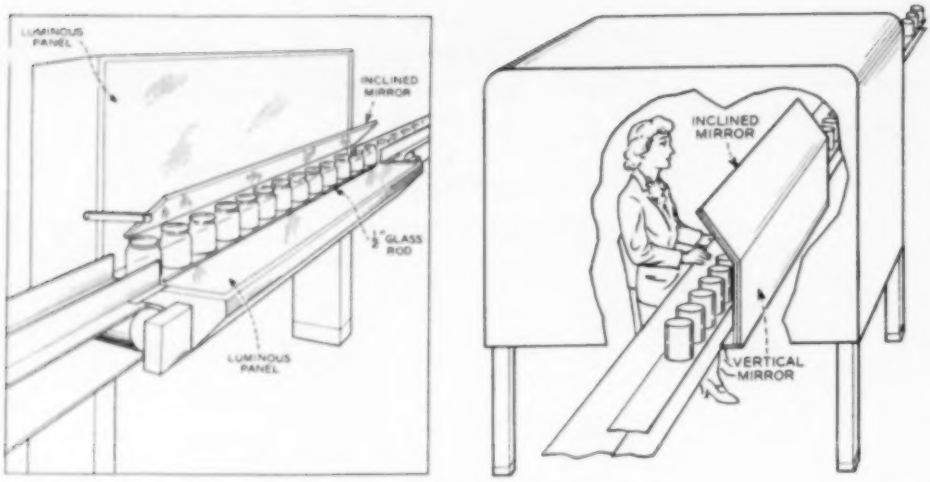
As a result of the cumulative experience of these committees, the techniques of preparing a lighting prescription for specific industries has developed in a fairly definite pattern. Actual operation, of course, varies somewhat with the personalities of the committee members. A typical example of the organization of an industry study committee is that of the Committee on the Lighting of the Silk and Rayon Weaving Industries. This instance is described since the writer, a member of the committee, is thoroughly familiar with the details.

The Chairman was a Central Station Lighting Engineer, selected by the Chairman of the main committee. Other members were: three sales engineers from three lamp companies; a sales engineer from a manufacturer of industrial lighting equipment; and a plant engineer of a rayon weaving company. Quite frequently several engineers from industry are included.

The first step was to contact several silk and rayon manufacturing companies and secure cooperation in making studies, taking photographs, etc. While one company with two plants was selected for the bulk of the work, arrangements were made to check these studies in two other plants.

With this background the committee held several meetings to outline the scope of the work and estimate the equipment and man-hours necessary to gather the basic data. The result of the studies indicated that the full time of a skilled lighting engineer would be required for a period of from three to six months to conduct the engineering analysis. Since none of the committee members had the necessary man-power available, one of the lamp manufacturers volunteered the services of an experienced investigator for the period of these studies. The expense of drafting, etc., was assumed by the Central Station.

The field engineer took up his residence in Chester near the factory of the Aberfoyle Manufacturing Company. His first step was to get acquainted with the personnel, including the operators, and



Lighting for Canneries

(Left) Glass jar inspection booth with horizontal and vertical translucent glass panels illuminated by fluorescent lamps behind.

(Right) Tin can inspection booth interior should be illuminated so as to have a brightness of approximately 400 foot-lamberts.

get an overall picture of the operation of the mill and the problems involved. He reported at frequent intervals to the Chairman of the committee. The committee held frequent meetings and guided the course of the work. Various members supplied the instruments required, such as Visibility Meters, Photometers, Brightness Meters, etc. Discussions as to final illumination levels, type and arrangement of equipment, etc., were made at the plant by the whole committee. The final report included a flow chart of the plant, isometric blackline sketches of various operations, showing distribution of light desired, and photographs illustrating specific principles. Members of the committee visited the Aberfoyle plant in Norfolk, Va.; the Wm. IX plant, New Holland, Pa.; and the Stahle silk plant in Lancaster, Pa. The completed report was presented before the I.E.S. Conference at White Sulphur Springs in 1937.

From the above account one can get an idea of the amount of work involved in an industry study. In common with most I.E.S. Committee work, manpower, and expense is contributed quite generously not only by the lighting industry, but in many cases by the industry under study. Once this information is released it is available to lighting engineers and industry in general, so that the overall effect is a saving which is participated in by all concerned. Such an activity will, of course, never reach its peak efficiency while it is handled on such an informal basis. Some arrangements should be made to make available the services of competent field investigators. The committee chairmen who have handled these enterprises are to be commended for their excellent supervisory work over and above the call of duty.

Technique of Industrial Lighting Studies

The benefits of good lighting in industry may be grouped under three headings: direct benefits, fringe benefits, and morale.

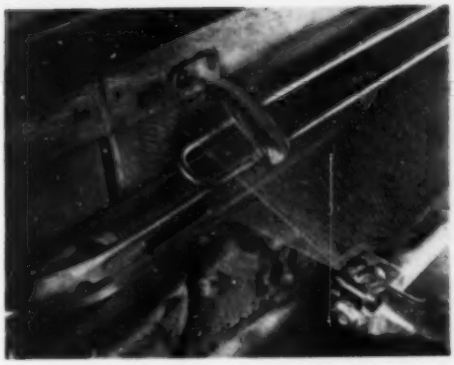
Direct Benefits.—Under this heading are included increased production, and decreased spoilage. Increases in production attributable to improved illumination are possible only when the speed of operation depends on the speed and accuracy of seeing. An automatic machine works as fast in total darkness as under the best lighting conditions. For example, if a loom has a peak efficiency of 90 per cent, good lighting can increase the volume of production only by reducing the time that the loom is stopped for adjustment, below 10 per cent. When the task is broken down in this manner between visual and automatic work, it is relatively easy to predict whether or not a change in illumination will actually increase the quantity of finished goods. However, while the loom is running the operator is constantly on the lookout for

breaks. These faults, if not detected immediately, result in defective cloth. In this case good lighting may cause an increase in production of first grade merchandise, since seconds must be repaired and therefore cost more to make and sell for less. Quite frequently it is difficult to give any accurate estimate of the value of illumination because of the presence of other variables. For example, in certain instances air conditioning might be of even greater importance than lighting.

Fringe Benefits.—Other benefits resulting from good lighting are even more difficult to evaluate economically. One of these is safety. Insurance records indicate that possibly 15 or 20 per cent of all industrial accidents are attributable to poor lighting. In specific cases this may be very hard to verify. Obviously, if a plant has one fatality in one year, and in the following year, after a change in lighting there are no fatalities, we cannot say that lighting has reduced the chance of fatality by 100 per cent. In an industry study it is necessary to investigate the safety angle but we must depend largely on experienced judgment to determine whether or not a given lighting system is to be accepted from the safety standpoint.

Closely allied with the matter of safety is that of fatigue. We know that certain lighting systems are more comfortable than others. We even have elaborate empirical systems for evaluating glare, but unfortunately, there is no generally accepted method of measuring ocular fatigue. Reduction of fatigue of this type may bring about an increase in production even though the task is not visual. Only adequate records covering a long period of time, carefully compared with control groups, can tell the complete story.

Another fringe benefit which is possibly considerably more important than the name would indicate, is economy of floor space. One important phase of modern production is the handling of materials in the process of manufacture. Moving assembly lines, conveyor belts, and overhead cranes, are now supplemented by motor driven trucks sometimes with trailer attachments so that the modern factory floor is crisscrossed with traffic lines. Space is at a premium so that good lighting is necessary to move materials accurately and swiftly. Sometimes high level lighting is justified from the standpoint of improved visibility for the operator of an overhead crane which may be as much as 70 to 80 feet away. These problems are all part and parcel of the American system of making more goods for less money. The illumination necessary for optimum speed in the handling of materials may well be the determining factor in the design of an industrial lighting system.



Lighting for Woolen and Worsted Textile Mills

In the loom above, the warp is the long threads that move up and down as controlled by the heddles. The filling thread passes back and forth through the warp threads as the shuttle is propelled from side to side.

Morale.—A third benefit is the provision for favorable surroundings for highly paid, highly skilled workers. In a time when factory workers are making from $5,000 to $10,000 annually, and in some cases more, common sense would indicate that a favorable surround for work would be almost mandatory. Workers still spend most of their daylight hours indoors working by artificial light. Little has been done to provide an interior which will induce a feeling of relaxation and comfort, thus making work a pleasure. The first natural step in this direction is to supply sufficient high quality illumination to make quick, accurate, and safe seeing easy. The next is to brighten the surroundings with light finishes in appropriate colors. The first organized step in this direction was made in 1941 after a Conference paper was presented showing studies of the effect of painting machines in two light-contrasting colors. No persuasion is needed to induce the management of a dairy or other food manufacturing plant to finish all surfaces in light colors. While this is done primarily for health, it does produce a more cheerful atmosphere for working. Some factories are now installing an office type of luminaire in order to improve the general atmosphere of the place. Much of the industrial lighting equipment now offered to the public has an upward light component from 6% to 25%. Some companies will supply industrial luminaires in any one of the several light colors.

When the above matters are taken into consideration, it doesn't require too much imagination to see that the problem of supervision has been greatly simplified. The foreman can see what is going

on and there is much less tendency to slow down in this kind of atmosphere.

One of the problems that must be solved by industry study committees is that of specialized lighting. From the standpoint of appearance, economy, and maintenance, the uniform general lighting system is ideal. But this arrangement falls down in many special cases such as inspection of bottles, seeing scribe marks on polished metal, deep boring, jacquard looms, cutting wires for electronic tubes, and many others where the lighting requirements are individual and require specialized supplementary lighting equipment. One subcommittee has analyzed the whole problem of supplementary lighting. Its report lays down certain basic principles which greatly simplify the task of engineering this type of lighting in an industry specification.

The above discussion should serve to indicate the type of action which goes on in the various industry committees. It is essentially a team work activity in which each one contributes from his experience something that will make the finished product a little better. Where possible, procedures are based on measurement. Visibility, brightness meters, etc., as well as the more common photoelectric photometer, have contributed much to the accuracy of the work. Where empirical methods must be used they are based on the combined cumulative experience of lighting and industry engineers.

The final report of the study committee contains a complete analysis of the lighting and seeing conditions in that particular industry in such form as to be readily usable. Briefly, it starts with handbook information as a base and develops a prescription. Sometimes the recommendations of illumination levels may be at variance with those published in the I.E.S. Handbook. This is not inconsistent since handbook information generally originates in technical committees. In many cases brand new techniques are developed. One example of this phase of the report is the glass jar inspection booth developed by the Committee on the Lighting of the Canning Industry. Sometimes an entirely new type of luminaire is produced. This was the case in the imposing stone luminaire developed by the Committee on the Lighting of the Printing Industry.

The photographs, black line sketches, and other forms of illustrations make available a wealth of detailed information entirely beyond the scope of the Handbook. The activity in these committees truly reflects the current progress in the vast field of industrial lighting. Although these committees operate entirely without funds from the Society, a lively interest has been sustained over a period of 16 or 17 years. Many men, some not members of the the I.E.S., have contributed freely of their time and talent to make this activity valuable and effective. It has done much to smooth the way for the Eyes of Industry.

Lighting for Machining of Small Metal Parts
Micrometer caliper properly lighted by a source of large area and low brightness.

Bibliography

Brainerd, Arthur A.: "Quality Industrial Lighting," *Electrical World* (February 1928, March 1928).

Brainerd, Arthur A.: "Factory Lighting to Fit the Facts," *I.E.S. Transactions* (1935).

Jackson, D. C.: "Lighting in Industry," *Journal of the Franklin Inst.*, p. 283 (March 1928).

Ferree & Rand: "Effect of Light on Ocular Functions," *I.E.S. Transactions*, p. 69 (1922).

Cobb, Percy W.: "Some Experiments on Speed of Vision," *I.E.S. Transactions*, p. 150 (1924).

Barker, J. W.: "Technique of Economic Studies of Lighting in Industry," *I.E.S. Transactions*, Vol. XXIII, No. 2, p. 174 (1922).

Shoemaker, George E.: "Synthetic Lighting," *I.E.S. Transactions*, Vol. XXVII, No. 3 (March 1932).

Brainerd, Arthur A.: "Improved Vision in Machine Tool Operation by Color Contrast," ILLUMINATING ENGINEERING (December 1941).

Brainerd, Arthur A.: "Salvaging Waste Light for Victory," ILLUMINATING ENGINEERING (December 1942).

Weston, H. C. (Great Britain): "Illumination and the Variation of Visual Performance with Age," *1931 Proceedings, C.I.E.*

Kreuger, Harry (Sweden): "Economics of Interior Lighting with Special Reference to Building Construction," *1931 Proceedings, C.I.E.*

Touw, L. M. C. (Holland): "Preferred Brightness Ratio of Task and Its Immediate Surroundings," *1931 Proceedings, C.I.E.*

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A Study of Eye Complaints From Fluorescent Lighting

By WILLARD ALLPHIN

OFFICE MANAGERS and illuminating engineers alike have sometimes had baffling experiences where employees complained of a new fluorescent lighting installation even though it seemed to follow the established rules of good lighting practice. In many cases, it is known that one employee is influenced by another in thinking that "the light bothers my eyes," but it is still worthwhile to try to establish what started the first employee in that direction.

Dr. Ernst Wolf has proposed[1] that the small component of ultraviolet below 400 Angstroms, which is present in the radiation from a fluorescent lamp, has a deleterious effect upon vision. He agrees that the same kind of radiation is present to a still greater degree in sunlight but apparently feels that we would be better off without this also if we are to perform visual work after such exposure.

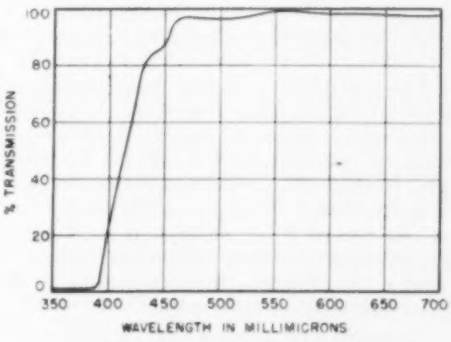
His work indicates that a subject who has been reading for a few minutes under fluorescent lighting which contains this ultraviolet component, returns more slowly to a fully dark-adapted state than he does after reading for the same length of time under the same amount of illumination from which the ultraviolet component has been eliminated. Since we perform our ordinary workaday tasks at levels far above those in which dark adaptation would be involved, it is difficult to see that the dark adaptation has much meaning except in such special cases as night flying, or night lookout duty on a ship.

The differences in dark adaptation found by Wolf were not confirmed at a brightness level of 20 footlamberts by investigators[2] at the Medical Research Laboratory of the U. S. Naval Submarine Base in New London. Here the subject read under white fluorescent lamps unshielded, under white fluorescent lamps shielded by acrylic plastic having a transmission of only 12 per cent at 3650A, and under daylight incandescent lamps. There was no significant difference in rates of return to a dark-adapted state.

The investigators did find a difference after exposure to a brightness of 165 footlamberts from a quartz-mercury lamp, but experiments were not made with fluorescent lamps at this brightness level.

In another Navy experiment, performance tests involving the cancellation of Landolt rings under fluorescent, ultraviolet-shielded fluorescent, and incandescent illumination showed no significant differences.

However, on the chance that some few individuals who are particularly sensitive to light and who may really need to wear tinted lenses outdoors in sunlight might be affected by the slight amount of ultraviolet in fluorescent illumination, a field test was set up in cooperation between Sylvania Electric Products Inc., and the Aetna Casualty & Surety Company. The Aetna phase of the experiment was under the direction of Mr. Roger T. Waite. Eighty-one employees were moved from an old building having an illumination level on the desks of 8 footcandles to a new building having an average maintained illumination level of 70 footcandles. The new area was divided into two parts making the portions approximately equal in shape and amount of daylight received. In one section, the white fluorescent lamps were coated with a plastic solution which cut off radiation below 4000A without appreciably affecting the visual radiation. The transmission of the filter coating is shown in curve. In the other section, the white fluorescent lamps had no filter coating.



Transmission of filter coating used on lamps.

A paper presented at the Northeastern Regional Conference, I.E.S., Swampscott, Mass., June 19, 1952. Author: Sylvania Electric Products Inc., Ipswich, Mass.

TABLE I.—Breakdown of Answers to Questionnaire.

1. What do you think of the lighting in your new location?		**Very Good**	**Good**	**No Opinion**	**Poor**
	Filtered area	45%	55%	0	0
	Unfiltered area	61%	35%	2%*	2%*
2. How does it compare with the lighting in the old location?		**Much Better**	**Better**	**No Difference**	**Worse**
	Filtered area	58%	42%	0	0
	Unfiltered area	73%	23%	2%*	2%*
3. Did your eyes ever feel tired at the old location? If so, how often?		**Daily**	**Often**	**Sometimes**	**Never**
	Filtered area	12%	30%	27%	30%
	Unfiltered area	27%	31%	19%	23%
4. Do your eyes ever feel tired at the new location? If so, how often?		**Daily**	**Often**	**Sometimes**	**Never**
	Filtered area	0	6%	39%	55%
	Unfiltered area	4%	8%	31%	57%
5. At the old location, did you ever have headaches which you felt were caused by eyestrain? If so, how often?		**Daily**	**Often**	**Sometimes**	**Never**
	Filtered area	3%	12%	30%	55%
	Unfiltered area	4%	23%	25%	48%
6. At the new location, do you ever have headaches which you feel are caused by eyestrain? If so, how often?		**Daily**	**Often**	**Sometimes**	**Never**
	Filtered area	0	3%	24%	73%
	Unfiltered area	0	2%*	27%	71%
7. Is the principal light you read or work under at home incandescent or fluorescent?		**Incandescent**	**Fluorescent**	**Both**	**No Answer**
	Filtered area	79%	6%	3%	12%
	Unfiltered area	86%	2%*	6%	6%

*Note that a figure of 2 per cent in the unfiltered area represents only one person.

Thirty-three men and women worked in the filtered area, and forty-eight in the unfiltered. No one knew about the test except the Chief Engineer and the Office Manager and it was hoped that as soon as the employees were moved from a low level of illumination to a considerably higher one, there would be some spontaneous complaints. Actually, no complaints nor comments were received on the lighting from the time of the move in August 1950, until a questionnaire was given to each employee in November 1950. The questions and answers are given in Table I. In addition, question No. 8 asked for comments. These were varied, ranging from "I think that the headaches are caused by poor air circulation in the building" to "Happy as a lark!"

After a preliminary study of the questionnaires, six of the employees were interviewed. In one case, it was established that the employee had misunderstood the questions and felt that her headaches were definitely due to ventilation, not lighting; and in another case, it was found that the displacement of some fixtures by air conditioning ducts, and a bad arrangement of filing cabinets had produced a "pocket" in which the illumination was only one-third that of the rest of the room.

Four cases were discussed with an ophthalmologist and one of these, he felt, did not need to be examined because he had examined her only six months earlier. She had indicated a preference for the old lighting on her questionnaire. She has had at least two nervous breakdowns and a serious surgical operation in recent years, and he feels that lighting is merely a "scapegoat" with her. This employee works in an unfiltered area.

The remaining three employees were examined by the ophthalmologist. A summary of the complaint and the complete report of the ophthalmologist for each case follows:

Miss B. T. (filtered area) said the new lighting was too bright and tired her eyes more than the old had. "I examined Miss B. T. on 1/3/51. She had no complaints, and had never worn glasses."

"The lids, conjunctive, cornea and extraocular muscles were entirely normal. Vision in each eye was 20/20, and Jaeger 1 for near. Homatropine refraction revealed an inconsequential error of refraction. Both fundi were normal. No glasses were recommended."

Miss L. S. (unfiltered area) preferred the new system to the old, but said that she still had occasional headaches. "Miss L. S. was examined by me on 1/6/51. She had no complaints, and had never worn glasses.

"The lids, conjunctive, cornea and extraoccular muscles were entirely normal. Vision in each eye was 20/20, and Jaeger 1 for near. Refraction done under homatropine revealed a very mild compound hyperopic astigmatism, insufficient to warrant glasses. Both fundi were negative."

Mrs. M. G. (filtered area) considered the new lighting system to be a little better than the old, but said that her eyes tired more under the new system. "Mrs. M. G. was examined by me on 1/9/51. She complained to me of smarting, burning and itching of the eyelids. A pair of glasses had been prescribed by someone a few years ago. She has not been wearing them.

"The lids, conjunctive, cornea and extraoccular muscles were normal. Vision in each eye was 20/20 and Jaeger 1 for near. Refraction was done, and revealed a hyperopia of 1 diopter in each eye. The glasses which she had were a +1.25. Fundi in each eye were normal. On further questioning, she told me her housework had to be done after a full day's work in the office — also, that her husband has odd hours of employment. He often leaves the home at 2:00 A.M., and at times works in the late evening. It was evident to me that this patient is under undue nervous tension, to which I ascribe her symptoms. She was told also to continue to wear her glasses for close work."

While there is an insufficient number of subjects for a detailed statistical analysis, it seems evident from Table I and from the special reports, that the small amount of ultraviolet radiation present in the standard fluorescent lamps is not causing any specific 'eye strain." Not only is there no significant difference between comments from the two areas, but no case in which a detailed examination was made leads to any conclusion which can be tied up with the lighting other than the one where the footcandle level was considerably lower than in the rest of the room.

In contrast with the considerable number of people involved in the foregoing, an individual case was studied in another city, where the subject considered himself very sensitive to fluorescent lighting. He reported severe headaches and a feeling "like a steel band around the head" when working under fluorescent, unless he wore tinted glasses over his regular prescription. The subject's physician (an internist) and his ophthalmologist both felt that his troubles were due to causes unrelated to illumination or vision; but, because the tinted lenses he was using actually did cut off the ultraviolet, it was decided to make a test. Four more pairs of tinted "slip-on" lenses were prepared, as follows:

1 Dark Tint	Transmits Ultraviolet
2 Light Tint	Transmits Ultraviolet
3 Dark Tint	Absorbs Ultraviolet
4 Light Tint	Absorbs Ultraviolet

Numbers 1 and 3 had exactly the same appearance, and numbers 2 and 4 likewise appeared to be identical. The subject was asked to wear his own glasses and the four new pairs, in any order he chose, for one week each. At the end of the five-week period he felt that all of the glasses relieved his trouble, but was unable to indicate any pair of glasses as being better than another. By this time, he had reached his own conclusion that he was equally sensitive to sunlight, incandescent lighting and fluorescent lighting and that when wearing any one of the pairs of tinted glasses fluorescent was as acceptable as incandescent lighting.

The door will remain open to further studies of fluorescent lighting complaints, but it can be said that neither the general office test nor the individual test described here, revealed anything peculiar to the radiation from a fluorescent lamp which would cause eyestrain, headaches, or similar complaints.

References

1. Zigler, M. J., Wolf, E., and King, E. S.: "The Influence of Surround Brightness and Short Wave Components of Radiation on Dark Adaptation." *Journal of the Optical Society of America*, Vol. 41, No. 5, p. 354 (May 1951).

2. Sexton, M., Malone, F., and Farnsworth, D.: "The Effect of Ultraviolet Radiation from Fluorescent Lights on Dark Adaptation and Visual Acuity." Medical Research Laboratory Report No. 169, Vol. 9, p. 301 (1950) U. S. Naval Submarine Base, New London, Conn.

Questions on Light Sources

The I.E.S. Committee on Light Sources, under the chairmanship of E. H. Raddin, is prepared to answer questions of general interest on light sources. Readers are invited to submit such questions to be considered for publication. Questions should be sent in care of Society Headquarters.

General illumination levels of 100-150 footcandles in a carefully engineered seeing environment have proved practical in this Metal Shop, where both quality and quantity of illumination are needed.

Comfort With High Levels

WORK DONE in this shop is varied and the tolerances are apt to be close, +.001 −.000. Here are made all working samples for the Engineering Laboratory. Most critical seeing task is in layout work. The full size of the finished product is often less than half an inch in diameter and from one-eighth to half an inch thick.

This room had been lighted by the usual industrial method to 60 footcandles maintained. It was found that in winter all critical work stopped when daylight faded, sometimes as early as three o'clock. Too many pieces were spoiled by continuing under "poor" seeing conditions of 60 footcandles, low quality lighting.

For practical purposes, the room was "divided" theoretically in half lengthwise. The work in one half was critical. Here were the work benches and lathes. In the other half, the 60 footcandles was sufficient. Luminaires having a 40 per cent upward component were installed on the same spacing in the latter half, and one extra row used over the work benches.

Our color scheme is as follows: machines and wall above dado are light green. Dado and wall below are "dado" green; the ceiling is white.

When the picture was taken, at 10:00 p.m. one evening in March, there were 140 footcandles on lathes and work benches. This will settle down to 110 footcandles maintained. Supplemental lighting had been installed on most machines during the past two years, and it is interesting to note that these lamps are now used by only one man, a workman who has been having trouble with his eyes.

To walk into the room without any knowledge of the installation and be asked to estimate the footcandle level on the benches invariably drives home the exceptional quality of the lighting. Many I.E.S. members have been asked this question and their estimates run from 40 to 65 footcandles. It is as hard to estimate as the level in the shade of a tree on a bright day. This installation is convincing proof that 100-150 footcandles of general illumination are practical where quantity and quality are needed.

Data submitted by George E. Pieper, Materials Engineer, Spencer Thermostat Division, Metals & Controls Corp., Attleboro, Mass. Photography by courtesy of Metals & Controls Corp.

Specifications For Production Lighting

By GEORGE J. TAYLOR

THE CONCEPT that lighting for industrial areas should approach comfort levels now accepted for offices is nowadays pretty well conceded in lighting "shop talk" and from the platform. In practice, however, this concept still has a long way to go.

In discussions on quality in industrial lighting—and this is now a favorite topic everywhere—a confusing issue is the very diversity of conditions found in industrial areas. Perhaps we do not think of an industrial area in its proper sense. For some reason we most frequently visualize a foundry, steel mill, forge shop or a dirty machine shop. Actually, the industrial lighting field applies also to clean assembly areas, an air-conditioned inspection room, a laboratory or an engineering department. In these terms, it might better be designated "production lighting"—lighting for all areas where production is the important factor.

For the lighting of these diversified production areas, the lighting industry has developed equally diversified tools. Each would seem to have its useful application, in varying degrees of the total. In Table I, an attempt has been made to classify the several lighting "tools," or types of industrial luminaires, in terms of the degree of its application to various factory conditions. Just as a workman would not choose a wood chisel to trim down a metal surface when a file should be used, so an industrial luminaire should be selected for the job on hand.

Types of Luminaires

The first luminaire shown in the table is the relatively new high-wattage, silvered, reflector-type lamp. Such a unit provides a distribution with all its light downward. It is available as a high wattage filament lamp and also as a mercury lamp. Included in this classification might be the 3000-watt mercury lamp with its open reflector. These are all high brightness sources.

Since there is no upward light it might be considered that there is no place for these systems when we consider comfort of seeing. However, they do have a definite place in industry where low first costs and low maintenance costs are important. The general application for systems of this nature would find itself in foundries, steel mills, forge shops and so forth. As indicated in the table, this "tool" might be considered to have a useful and proper application in approximately 5 per cent of production areas.

The second classification shown includes high bay luminaires which provide good shielding (20/45-degree) and having an upward light component of at least 5 per cent. Such units are desirable, to avoid ceiling gloom and to add comfort by the reduction of brightness ratios. Equipment of this nature is available for use with incandescent lamps, as well as mercury lamps.

POTENTIAL APPLICATION OF LUMINAIRES FOR PRODUCTION LIGHTING

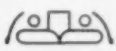
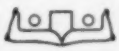
DESCRIPTION	TYPICAL LUMINAIRE	TYPICAL DISTRIBUTION	POTENTIAL APPLICATION
1. SILVERED HIGH WATTAGE REFLECTOR LAMP		0% ↑ 100% ↓	5%
2. HIGH BAY REFLECTOR UNIT		5% ↑ 95% ↓	5%
3. FLUORESCENT PORCELAIN REFLECTOR UNIT		10% ↑ 90% ↓	55%
4. FLUORESCENT PORCELAIN REFLECTOR UNIT		25% ↑ 75% ↓	20%
5. FLUORESCENT METAL OR LUMINOUS SIDED UNIT		50% ↑ 50% ↓	10%
6. LUMINOUS-INDIRECT UNIT OR LUMINOUS CEILING		90% ↑ 10% ↓	5%

TABLE I.

Substance of a paper presented before the Canadian Regional and Great Lakes Regional Conferences of I.E.S., May 1952. Author: Day-Brite Lighting Co., New York, N. Y.

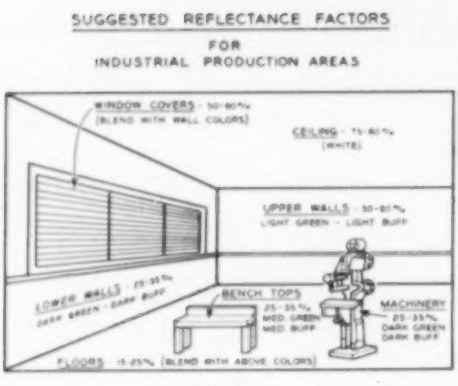


Figure 1.

General application of luminaires in this classification might include heavy machining areas, paper manufacturing, erection shops and so forth. Their degree of usefulness is estimated as about 5 per cent of production applications.

Classification 3 shows the type of industrial luminaire designed to throw a minimum of 10 per cent uplight. Equipment of this nature is designed to comply with heavy duty machines. Such units should have sturdy channels to which porcelain enamel reflectors can be quickly detached or attached for maintenance and cleaning purposes. It is interesting to note that luminaires of this type followed the trend of RLM incandescent designs. When fluorescent units of this type were first available the outer surfaces of the reflectors were dark green. A few years later they were lightened slightly using a battleship grey color. Shortly thereafter, they were found in light grey. All these improvements in light colors reduced the brightness ratios from the outside surface of the reflector to the inside surface.

Progress has now continued to the point where these industrial luminaires will be finished in white on the inside as well as on the outside of the reflector. These units will be made available in the standard RLM shielding at 13 degrees crosswise. Also available will be the longitudinal louver which allows for 26-degree shielding crosswise. Another accessory part will be an eggcrate louver which can readily be attached to provide shielding of at least 25 degrees crosswise, as well as endwise.

Applications of this type of unit would be found in machine tool rooms, airplane assembly, automobile manufacturing, rubber goods, leather manufacturing and so forth. They should find application in about 55 per cent of production areas.

Classification 4 (See Table) is a new development in lighting for production. Such a unit must be constructed ruggedly for "industrial" application. It should be an all white, all porcelain unit having a distribution of light with 25 per cent upward and 75 per cent downward. Specifications for a unit of this nature might be as follows:

1. Adequate shielding	30/20 degree
2. Sufficient uplight	20/30 per cent
3. High efficiency	70/80 per cent
4. Low maintenance	Open-top
5. All white reflector	Porcelain enamelled
6. Rugged construction	For satisfactory service

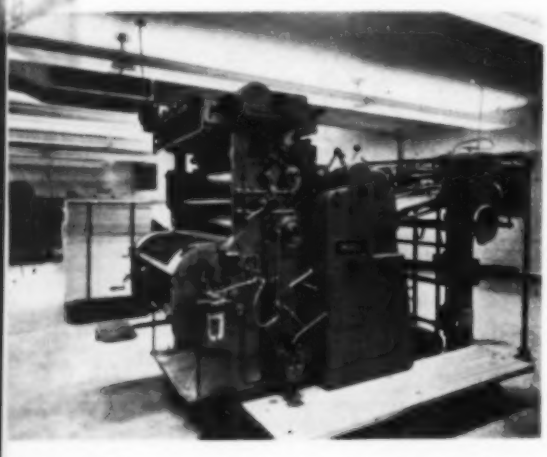
General applications of a unit of this type would be in machine tool rooms, printing industry, textile mills, sheet metal works, assembly, inspection and so forth. Degree of application is estimated at approximately 20 per cent of industrial areas.

Classification 5 is a luminaire with a distribution of upward light as high as 50 per cent. The unit should be well shielded complying with commercial type units at 35/25-degree. Included in this classification might be Alzak aluminum troffers with parabolic reflectors for low brightness control.

General applications might include laboratories, planning departments, engineering offices and so forth, or about 10 per cent of the production applications.

Classification 6 is a lighting system where highest quality of illumination is essential. This would include luminous indirect luminaires with approxi-

Figure 2. This installation demonstrates the effective use of light colored machinery, light floors and wall surfaces, acoustical treatment and air conditioning, and lighting with high upward component. *Photo: Piaget Studio, St. Louis.*



mately 90 per cent of their light upward and 10 per cent downward. It would also include luminous ceilings with proper brightness control.

Application of systems of this nature would be in drafting rooms, engineering departments, design departments, art departments and so forth. The estimate of proper application of this tool is about 5 per cent of the total "production areas."

Steps to Quality

Considering the pace of today's industrial production, it is only fitting that the importance of the "quality story" in industrial lighting has come in for considerable attention. Industry has been called upon to make marked increases in output, work to closer tolerances and assemble smaller parts than have ever been known in the past. Seeing tasks, especially when it is considered that faster production is an element of importance, are more difficult than in earlier days.

The steps toward achieving quality illumination in industry are well-known to lighting men. In considering "which lighting tools to use for what industrial area," however, attention to quality or comfort and ease of seeing, plays an important part. In this connection, it might be in order to insert a word of warning with regard to "up-lighting." In specifying luminaires having various degrees of upward component, care should be taken that ceiling brightnesses in ratio to machine surfaces near the point of seeing do not exceed recommended practice. Neither should floor brightnesses exceed machine surface brightnesses lest discomfort result. It is essential that good brightness engineering be practiced throughout the area.

Figure 3. A typical condition for which the new high-wattage silvered high-bay reflector lamp was designed to serve is this 100-year-old foundry, in which first cost and maintenance problems were paramount. Sixteen of these lamps spaced on 16x27-foot centers, mounted at 22 feet, provide 30 ft-c, an increase from a previous level of 1 to 5 ft-c. This installation, made by H. M. White of the Consolidated Gas Electric Light and Power Co. of Baltimore, won first place in the contest of the Maryland Section for My Most Interesting Lighting Installation and received Honorable Mention at the East Central Regional Conference Semi-Finals in Pittsburgh. *Photo and data courtesy of Mr. White.*

Four major rules apply to quality in production lighting. First, level of illumination still remains a part of the story. While we have made great strides in raising the level of illumination in factories, the overall job, in terms of comfort, is still far from

Figure 4. Aluminum troffer units were designed for low brightness. The sides blend in with the ceiling. For better brightness engineering machines could have been lighter in color.

Figure 5. A level of 32 ft-c is provided by 685 300-watt glass-shielded units with 15-20 per cent upward light component, mounted on 10x15-foot spacing at a height of 14 feet.

comparable to conditions accepted for offices. The same may be said for other comforts now common to offices, namely air-conditioning and acoustical treatment.

A second major rule to seeing comfort is—attention to brightness ratios. Here again, office areas more often comply with recommended brightnesses. In factory applications ratios often exceed 500 to 1 and even 1000 to 1, as against the maximum brightness ratio of 80 to 1 anywhere within the field of view recommended by the I.E.S. Considering that industrial tasks are frequently much more exacting, the rule that brightness ratios be within recommended practice, becomes an important step to comfort.

Next, brightness engineering is an essential part of the quality story. Actually, this phase of the application of illumination has a direct bearing upon the first two items. For the best results in brightness engineering a balance between footcandles and footlamberts must be arrived at to result in best seeing conditions. To comply with proper brightness engineering the suggested reflectance factor for Figure 1 should be closely followed. Any deviation from the balanced reflectances shown may result in discomfort to workers.

Quality of illumination depends upon the proper application of the first three steps. When levels of ilumination are adequate, footlamberts controlled and brightness engineering balanced the result is comfort of seeing.

Summary

It takes people, men and women, to build planes, tanks and the products of peace. Their ability to build them fast and accurately depends on comfort of seeing. In specifying industrial lighting, follow the rules of good brightness engineering.

1. Get rid of dark ceilings but don't make them too bright.
2. Lighten up floors.
3. Brighten up machines.
4. Eliminate dark work surfaces.
5. Avoid harsh contrasts.
6. Relieve harsh shadows.
7. Cut down glare.

In specifying luminaires for production areas, remember there is some place for every luminaire, and a luminaire to suit every place. To do the job most economically and for the best results, they must be properly applied.

Register Now — It Is Later Than You Think

Send in your registration blanks to

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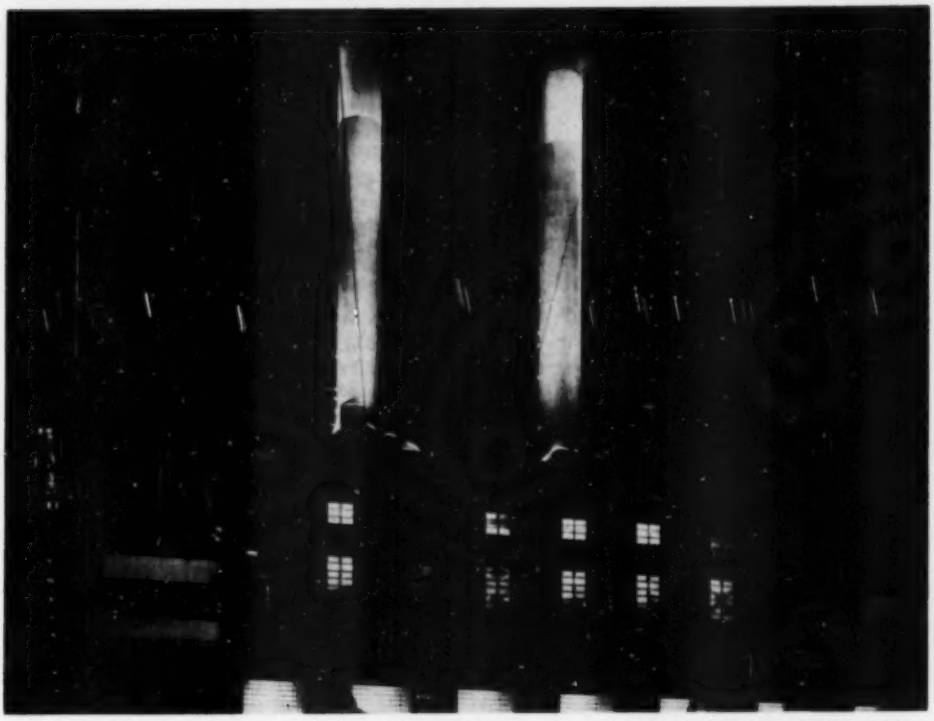
1860 Broadway, New York 23, N. Y.



INSTALLATION AT THE DUNKIRK STEAM STATION OF THE NIAGARA MOHAWK POWER CORP., DUNKIRK, N. Y.

Floodlighting Stacks

LIGHTING OBJECTIVE: To provide obstacle lighting for the stacks of a steam generating plant in accordance with the requirements of the Civil Aeronautics Authority.

GENERAL INFORMATION: The Dunkirk Steam Station on the shore of Lake Erie is directly on the airway between Buffalo and the West. The height of the twin stacks is 312 feet above ground and it was necessary to mark them in accordance with CAA requirements. Such obstacle lighting is usually done with luminaires suspended from disconnecting hangers mounted on the stacks, the luminaires being lowered to the roof on cables for maintenance. CAA obstacle lighting specifications require that the uppermost lights be six feet below the top of the stack. In this case the periodic use of scaffolds for maintenance purposes suspended from a trolley track at the top of the stack precluded the use of the usual luminaires and lowering cables. The possibility of high winds and severe icing conditions further indicated the desirability of floodlighting the stacks from the roof. Special permission for using floodlighting rather than obstacle lighting was obtained from the CAA.

The stacks are 13'6" top diameter, 64' on centers and rise 147' above the roof. The top portion of each stack is finished in gray paint with a reflectance of about 70 per cent; the remainder is finished in aluminum paint.

(over)

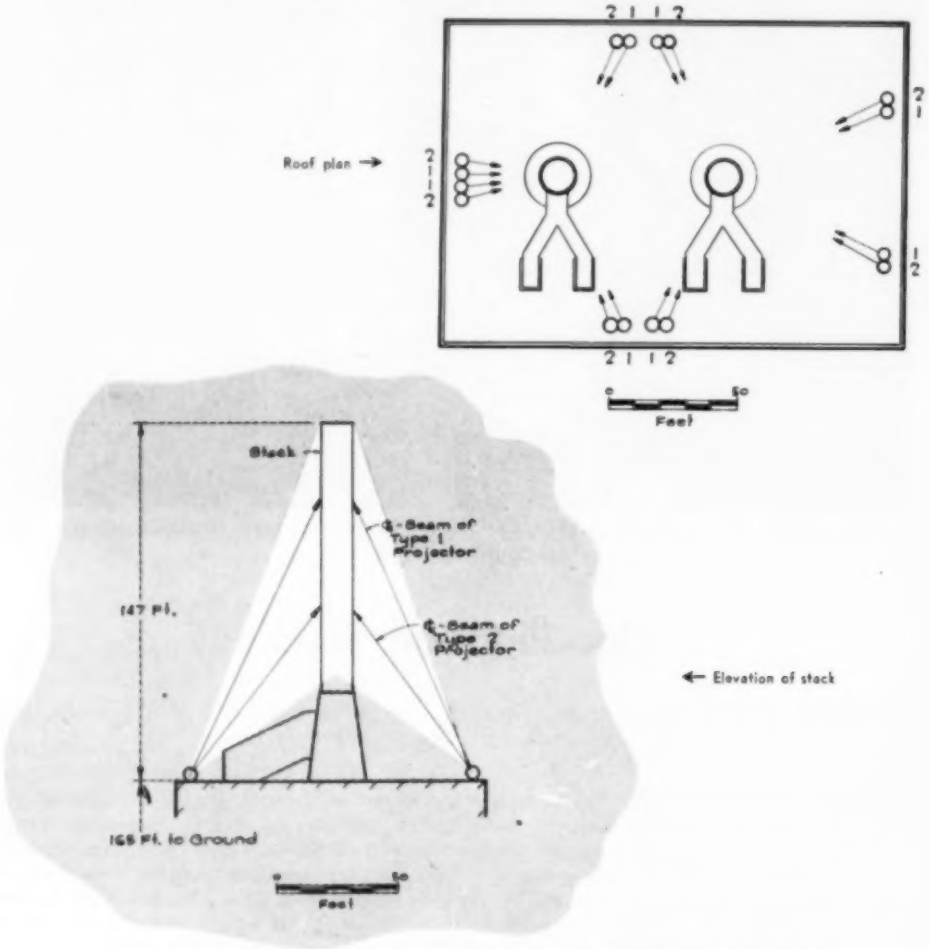
A.I.A. File No. 31-J

Floodlighting Stacks (continued)

INSTALLATION: The stacks are lighted by Crouse-Hinds enclosed projectors employing 1000-watt G-40 floodlight lamps arranged on the roof as shown:

(1) Type ADE-16 42743 with narrow beam reflector, plain lens and top hood; 11-degree symmetrical beam.
(2) Type ADE-16 42743 with narrow beam reflector and 50-degree vertical spread lens; 13-degree horizontal by 34-degree vertical beam.

The top third of the stacks is lighted to a calculated illumination level in excess of 15 foot-candles in accordance with CAA requirements.



Lighting data submitted by the Niagara Mohawk Power Corporation, Buffalo, New York, as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Techniques for Exposing the Industrial Saboteur

By CARL F. JENSEN

MOST OFTEN in discussing protective lighting we think in terms of protecting the exterior of the plants; the supply facilities such as power sub-stations, etc. This phase of protective lighting is, of course, very important, but some of the less apparent weak spots in our industrial operations also require our attention. Included in this category would be the safety of personnel, the protection and surveillance over special drawings, machine tool equipment, and employee identification, with particular emphasis on assurance that identification badges cannot be altered without immediate detection.

One important item requiring special consideration is the lunch pail. The innocent-appearing lunch bucket has frequently been a convenient means of removing small parts, important papers and even key mechanisms from the plant to the outside. Effective means of exposing the saboteur and sneak thief are in daily use in industrial plants. Some of these methods and materials, being the property of our national detection officers, cannot be discussed at this time. There are tricks, however, used by crime detection organizations which could be adapted easily to the industrial plant. Most of these involve the use of invisible energy, either in the short-wave radiations such as ultraviolet, or in the long-range radiations such as infrared. There are other devices; X-Ray equipment, photoelectric eyes, and just high levels of general illumination which may be used either individually or in conjunction with the above mentioned equipment, to forestall and uncover the surversive operations of the saboteur or his accomplice.

Exposing the Saboteur

The most important, but perhaps the least glamorous, ally of protective lighting is high levels of illumination. Too often when the lighting plans for an industrial plant are laid out, watchmen's area or the employees' entrance is given little or no consideration in terms of specific layout. Low levels of illumination in the order of 5 to 10 footcandles are quite common in industrial entrance areas. These levels are more an ally of the saboteur than they are help to the plant. Throughout the plant we think in terms of minimum levels of 50 footcandles, but often the entrance-way is ignored. Planned high-level illumination in the guard houses and employees' entrances would enable guards and watchmen to detect bulges under overcoats, extra prints stuffed in newspapers, tamperings with sealed lunch boxes etc. High levels are doubly important here because it is common practice to place on guard-house duty men well along in years — men whose seeing facilities have begun to decline. Light can and will improve these facilities to the extent that not only are things more visible, but the efficiency of the older eye is greatly improved. It is certainly a well known axiom that "while darkness is an ally of the saboteur, light is an important weapon to make the almost-honest more honest, and discourage thievery and even sabotage."

Ultraviolet offers another valuable assist to the plant protection group. Though equipment has been available for many years, fluorescence and phosphorescence have not been thoroughly explored for this application. Most of these devices are activated by invisible energies in the regions around 3600 angstroms, or what is commonly know in stage effects as blacklight. Materials which are completely invisible in normal light but which glow brilliantly when subjected to the invisible blacklight, are more numerous than is commonly realized. Most of the fluorescent materials are common inorganic materials completely harmless to humans, but are in effect, sudden death to the saboteur and criminally inclined. These materials, which basically invisible in ordinary light, glow brilliantly under blacklight, and are so light in weight they cannot be detected or even brushed or washed off. One might say a criminal can be caught *light* handed! If certain of the zinc compounds are used, for example on important documents, anyone touching these documents would immediately pick up a sufficient amount of the compounds or powders so that when examined under blacklight the hands would glow brilliantly. If every employee, upon leaving the plant, were required to submit to a blacklight inspection, any unauthorized personnel who handled the prints could be detained for questioning, while authorized personnel who showed the glow could be released.

Substance of a paper presented at the Clinic on Protective Lighting, conducted by the Chicago Lighting Institute and the Chicago Section of I.E.S. Author: Westinghouse Electric Corp., Chicago, Ill.

Employee badges could be treated with an invisible fluorescent material that would immediately show any tampering that had occurred on these identification badges. This could prevent such fiascos as were reported during World War II, when pranksters and others substituted their pictures with the photographs of anything from the Eiffel Tower to the east end of westbound animals, and even to Hitler's photograph. Some of the materials that are available today have the characteristic of fluorescing one color under so-called blacklight and fluorescing or even phosphorescing another color in other regions of ultraviolet.

With some of the materials available, it is possible to detect tampering with lunch boxes, closed after lunch period inspection, by either the fluorescence or lack of fluorescence on the tape that was used to seal the boxes. There are also available materials that will fluoresce under blacklight either the same color as the visible color or a different color. Such materials would immediately expose tampering since in many cases it would be hard to duplicate the fluorescent color on location, even though the visible color could be readily matched.

Badges could be coded by printing a few of the letters of the company name in a fluorescent color which was identical to its visible color. Portions of the badge might be treated with a phosphorescent pigment. These sections of the badge could be used to identify unauthorized badges or personnel in restricted areas merely by the phosphorescence or lack of it.

Safety Techniques

Both fluorescent and phosphorescent materials, with particular emphasis on the latter class, have been used in the past and could be used again for safety identification for marking such things as projections on machines, identifying the fireboxes, telephones, first-aid stations, and could even be used as indicator lines or marks to allow personnel easy access from a plant that has been blacked-out because of power failure or service interruption. Many fluorescent and phosphorescent compounds are now available on adhesive backed materials that can be fastened either permanently or temporarily to almost any surface. Such materials would lend themselves to easy changing of identification or marking. Exit signs are now available that glow for long periods of time after power has been turned off. The entire field of materials and their applications in the use of both fluorescent and phosphorescent materials is so great and varied, it cannot be adequately covered in the space here allocated. Any who would care to investigate further would find that there are many dyes, paints, materials and even cloths that fluoresce either naturally by accident or by desire.

Information on the use of infrared has been classified as secret for so long that very little can be said other than it is entirely possible by the use of an invisible beam of infrared, even in the dark, to detect the operation of suspected personnel during the periods when light is not available. It might also be a splendid adjunct to have in effect an infrared telescope available to watchmen or guards, located at strategic points throughout the plant, so that they could even peer into the dark corners, if there are any, and be thoroughly acquainted with actions in these shadowed areas. Another good use for infrared would be as an invisible barrier in combination with photoelectric cells so that when the beam is broken an alarm sounds at the house or plant protection headquarters. The beams can either be steady or modulated or pulsed — a pulsed beam has the advantage of being practically impossible to foul or block. The frequency of the alternations could be such that a flash light pointed into the receiver cell would not block the alarm even though the flashlight were moved across the cell rapidly. Such a system is now available from one of the major plant protection agencies.

Electronic devices of various sorts, some of which are available and others which could be readily made available, could be installed at the pass through points at the entrance of the plant so that metals in the form of tools, knives, etc., could be detected when employees or others pass through this invisible beam of radio energy. X-ray equipment similar to the type used by the medical profession for fluoroscopic examinations, are now available in relatively small sizes that could be readily installed at guard houses or pass-through points. With some of the new electronic magnifiers that are available, the contents of lunch boxes or pails could be very quickly examined without the need of opening these boxes. This type of equipment at present is expensive, but a small unit could be developed that would probably be well worth its price for the protection it affords.

In general, the imagination and the availability of some of the materials are the only restrictions that need be placed on the use of many of these invisible, semi-invisible or electronic devices that can aid or abet better plant protection and make it uncomfortable and/or impossible for the saboteur to operate.

Remember, that light and plenty of it is still the greatest ally available at the least cost to the plant protection group.

Characteristics of Porcelain Enamel As Used In The Lighting Industry

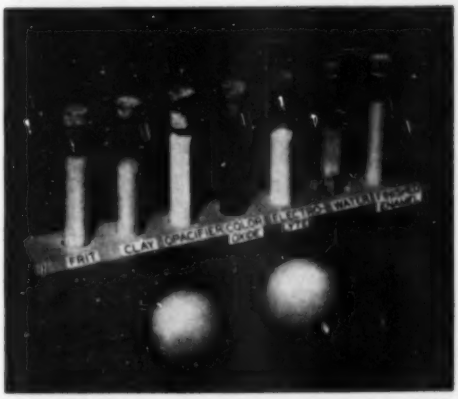
By ERIC H. CHURCH

ALTHOUGH porcelain enamel has been processed commercially for almost a hundred years in this country, and examples can be seen in many home appliances, the nature of the material and its application is still unknown to many in the lighting field.

The term, porcelain enamel, is often confused with paint enamels or baked synthetic enamels. It should be clearly understood that porcelain or vitreous enamel is an entirely different substance and product. By definition, a porcelain vitreous enamel is a material made from glass and fused on metal. Paint enamels are either made from synthetic resins or are paints with high varnish content baked at temperatures in the range of 300° F to 400° F, giving a high gloss, which is often confused with porcelain enamel finishes which are fused at 1500° F to 1600° F. Although porcelain enamel is a form of glasss, it has to adhere rigidly to metal, resist normal handling, withstand certain impact and handling tests, and withstand sudden temperature changes.

Generally speaking, porcelain enamel is made up of six basic materials: frit, clay, opacifiers, color agents, electrolytes and water. First and foremost is a mixture of quartz, borax, feldspar, soda ash, etc. which is proportioned correctly and then melted in a large refractory furnace at temperatures of 2200° F which gives a molten mass very similar to glass. After several hours this molten mass is run off to cascade from a spout-like orifice of the furnace into a huge tank of water. The sudden contraction of the molten glass, owing to the tremendous change in temperature, literally shatters it into a mass of fragments. The glass in this state is called "frit."

The second material in importance is clay. This acts as a floating agent necessary to hold the small particles of milled enamel in suspension in the water and also as a binder to hold the enamel in place on the steel after the water is dried out. The strength of the dried enamel, or "bisque" as it is called, before firing is largely dependent on the amount of clay used which is approximately 5 per cent in a mix. A good enameling clay lies between china clay and true ball clay. To prevent contamination of the enamels, this clay must be purified to remove foreign matter.



INGREDIENTS and the grinding media for porcelain enamel.

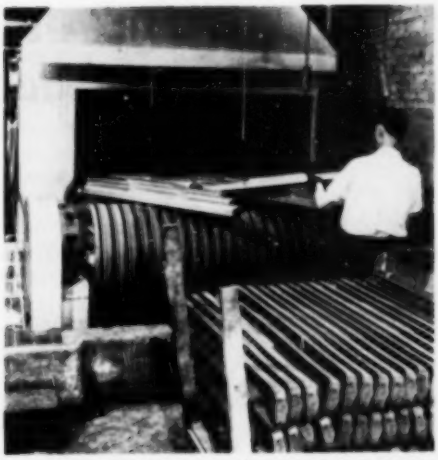
The third material is the opacifier. The opacity, or degree of whiteness, of the frit itself is not high enough to satisfy the demands of many industries, particularly the lighting industry, so materials called opacifiers are sometimes added. The most widely used opacifiers today are zirconium, antimony and titanium base. The amount of opacifier depends on the end use of the enamel and may vary from 1 to 3 per cent. With the development of the new highly-opaque titanium white enamels, however, during the past few years reflectance factors up to 90 per cent are attainable without the use of opacifiers. In these enamels, the opacity is developed by re-crystallization of titanium oxide from the molten glass on cooling.

The fourth class of materials used to make up the enamel is the electrolytes or the "set up salts." If an enamel is milled with only frit and clay it will not stay in proper suspension or "set up" correctly. The addition of certain salts or combination of salts corrects this condition. Some of the most common materials used are borax, soda ash, magnesium carbonate, epsom salts, potash alum, sodium nitrite and potassium carbonate. The quantity of

Author: In charge of Laboratory, Benjamin Electric Mfg. Co., Des Plaines, Illinois. Submitted by Chicago Section Papers Comm.

The Process

1. **POURING** a batch of enamel from a mill. Samples are taken and checked by a ceramics engineer.

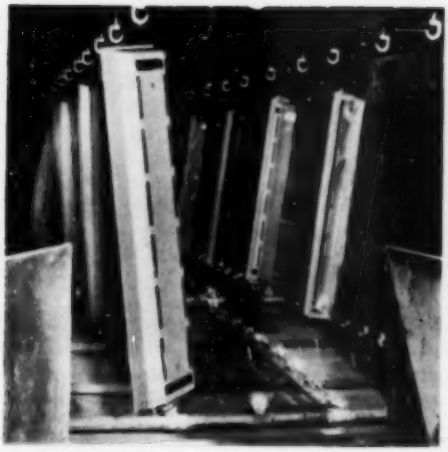


2. **PARTS LEAVING** a continuous "pickling" machine. It is most important that ware be thoroughly clean.

3. **APPLYING** the enamel on the reflectors (left) using the dipping process and (right) using the spraying process. After the enamel is applied to the ware, the water is evaporated by drying.

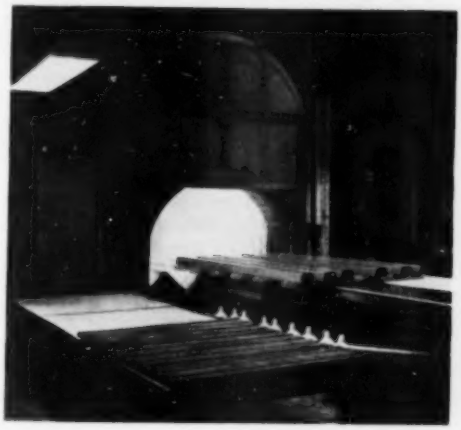
electrolytes in a mix varies from $\frac{1}{2}$ per cent to $\frac{3}{4}$ per cent.

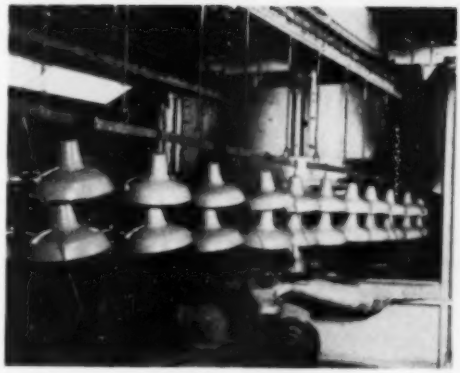
The coloring of porcelain enamel is obtained by the addition of color oxides or pigments either in the frit batch or at the grinding mill. However, the resultant shades can be influenced by the composition of the enamels. For example, zinc oxide in the enamel will brighten the blues but tends to deaden certain shades of green. The basis for white enamel is an opaque frit with or without opacifiers. Grey is obtained by adding black or grey oxide. Blue enamel is obtained by using a blue frit or the addition of blue coloring oxides to a clear frit. Almost all blue pigments are made from cobalt compounds. Yellow enamels are obtained by adding from one to three per cent yellow oxide to the opaque frit and red with the use of cadmium or selenium compounds. Black pigments are prepared by calcining compounds of iron, chromium, manganese, and cobalt. Final coloring of enamels is



4. **DRYING the ware. This must be done carefully to avoid scraping off the fine "bisque."**

5. **BURNING or fusing the enamel to reflectors. Top photo: Continuous furnace on a fluorescent reflector. Center photo: Box furnace on fluorescent channels. Bottom photo: Continuous furnace on incandescent reflector.**





also greatly influenced by processing, such as correct firing temperatures and so forth.

In addition to the above five basic materials, frequently certain other materials are added to the mill formula of enamels to serve special purposes, such as zinc oxides to cause the enamel slip to smooth out more easily in dipping operation or the addition of small amounts of feldspar to give the enamel a longer range in firing.

All materials necessary to make a "batch" or mix of enamel are carefully proportioned and then placed in a mill and with the proper amount of water, are ground to the desired fineness. The mill consists of a steel drum lined with special brick and arranged in such manner so as to revolve, using a grinding medium of porcelain balls. The mill is loaded approximately three quarters full with the frit and other materials, including water. The amount of water depends on the end use of the enamel; however, it may vary anywhere from forty pounds to sixty pounds of water per hundred pounds of frit. A load can consist of up to two thousand pounds, depending on the size of the mill. Grinding time may take up to eight hours. Samples are then taken from the mix and checked by a ceramic engineer to determine the suitability of the material.

The enamel is then delivered to the sprayers or dippers for application to the parts which, in the trade, are called "the ware." The "ware" itself must be fabricated from special enameling iron and the parts must be designed in such manner to be acceptable for the porcelain enameling process. After fabrication, the parts must be thoroughly

cleaned. This operation is one of the most important in the entire process. Foreign substances on the ware can cause blistering, lack of adhesion and other complications. Ware can be cleaned by loading baskets and submerging the entire basket in tanks, starting with an alkaline cleaner to remove oil and grease, a hot water rinse, a 7 per cent sulphuric acid bath to remove rust, etc., then a cold and hot rinse followed by a nickel sulphate dip to improve the bond of the enamel to the steel, followed by a very light acid rinse and then dipping the load into a neutralizer which both neutralizes the acid and retards rusting of the metal until the porcelain enamel can be applied. Cleaning ware or "pickling," as it is called in the trade, is also done by the spray method in which the ware passes through a machine ninety feet long and at various stages the cleaning operations are accomplished. As each part is fed separately on the conveyor belt, the part is treated separately by pressure spraying of each solution in the "pickling" machine. This, of course, gives much better quality control of the process and a cleaner metal for the application of the vitreous enamel.

After passing through the cleaning process the ware is ready for the application of the enamel. This is accomplished by either "dipping" which consists of submerging the ware in a bath of enamel, or by spraying the enamel on the ware by means of a spray gun as with paint. After the enamel is applied to the ware the water is evaporated by drying, leaving a powdered residue, finer than talcum. This is called the "bisque" and must be handled carefully as it can be scraped off easily. The ware is now ready to have the enamel fused to the steel. Just as glass must be brought to a high temperature to flow as a liquid, the "bisque" must also be heated to temperatures in the ranges of from 1500°F to 1600°F for several minutes until the porcelain enamel or "glass" flows as a liquid and enters the "pores" of the steel, and becomes keyed or bonded to the base metal.

Bringing the ware to the desired temperatures is accomplished with the use of box and continuous furnaces operated by gas or oil, in which the ware is either laid on bars or hung on hooks and by either conveyor chains or manually operated forks, inserted into the furnace and subjected to the temperatures necessary to fuse the glass on the metal. When the ware leaves the furnace, it has the appearance and characteristics of glass itself and actually the steel has now become coated with a sheet of glass, giving a durable and good-appearing finish.

In general, devices in the lighting field can be finished with porcelain enamel, paint, or metallic and chemical plating. The finish is used to provide a certain degree of corrosion protection, enhance the appearance of the product or is applied to obtain light control and the high reflectances necessary for reflectors. The choice of a finish to be used should be governed by the end use of the device, initial cost, and overall cost of an installation including both maintenance and amortization. The ultimate user of lighting equipment can often effect considerable saving with an understanding of the correct choice of finishes used in the lighting industry.

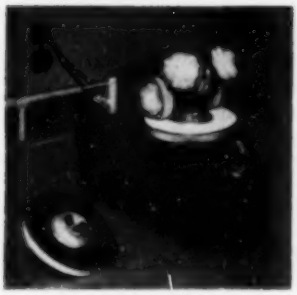
Testing Finishes

There are many recognized tests and much equipment for evaluating finishes. Most of these tests can be correlated to actual conditions so that the consumer can predict certain performances. The most common corrosion and performance tests are abrasion, scratch test, salt fog, humidity, weathering machine and most important, the use of "Mother Nature" in the form of outside and inside weather "decks."

The abrasion tester is a precision sensitive testing instrument for measuring the rate of wear of surface finishes subjected to rubbing abrasion. The wearing action of the abraser conforms to accepted testing practice as the Calibrase wheels closely parallel the rubbing abrasion encountered in actual service. The pressure of the wheels is regulated by weights that are assembled above abrasion media and are interchangeable from 1000 grams to 125 grams per wheel. The specimen to be tested revolves in the opposite direction to the wheels and after a predetermined number of cycles, correlation between the abrasive testing and certain "field wear" can be made. This test is extremely useful in determining the resistance of certain finishes to the rubbing action encountered in cleaning reflectors. It can be readily predicted which type of finish will give satisfactory performance. The abrasive action of normal shop handling can also be predicted and finishes suitable to withstand such type of wear can be chosen.

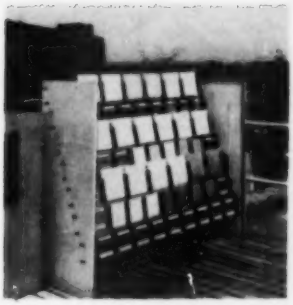
The shear hardness test is a quality of a finished surface to resist digs, scrapes and similar physical damage not classed as normal wear. It consists of a graduated Scale Beam with sliding weight for providing an adjustment in load from zero to 500 grams. A precision tool is mounted on the under side of the Scale Beam in line with the center of the specimen holder and is provided with a Tungsten Carbide edge precision ground. This tool cuts a shallow groove varying in width according to the load applied and the resistance of the finish to the shearing action.

Testing Finishes



Abrasion Test

Scratch Test

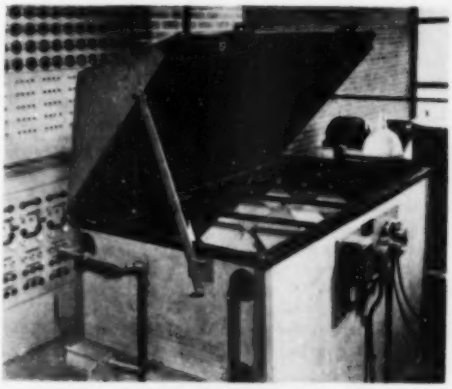


Roof Deck

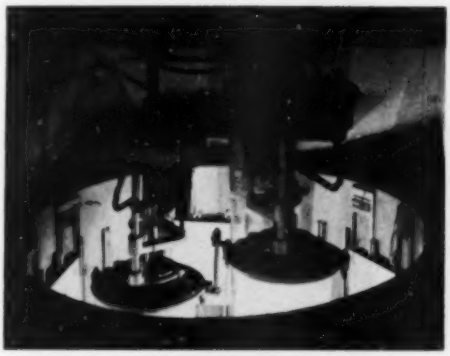
The salt fog machine is probably the most widely known method of testing finishes. It has been a stand-by of such agencies as the Army and Navy for years. Specimens to be tested are placed in the machine and, as the name indicates, are subjected to a salt fog. The salt solution is heated to 92°-97° F and should have a specific gravity of 1.126-1.157. The mixture is atomized and fed to the specimens at approximately 14 pounds P.S.I. Close examination of specimens after subjection to the test for 48 to 200 hours will determine relative resistances of different finishes. Correlation between actual service, such as in coastal areas, can give valuable data in predicting life of finishes.

Testing of specimens in the weathering machine subjects the finishes to the destructive action of sun, rain, heat and cold, causing breakdowns in a few hours, days or weeks similar to those resulting from months or even years in out-of-doors. The specimens are exposed to the radiation of carbon arcs and cold water spray. The radiation is the same as June sunlight at noon in Washington, D. C. The water spray on the specimens can be regulated to various cycles such as three minutes out of every twenty, etc. The specimens fastened in a drum come under the influence of approximately 123° F and are rapidly cooled to 60° F. Correlation between the tests made in the weathering machine and outside exposure makes easily possible the comparative values of finishes for outside use.

One of the most common tests for finishes is the "humidity cabinet." Here samples are subjected to a controlled atmosphere of temperature and humidity. These tests are run at temperatures from 100° F to 125° F and at humidities from 80 per cent to 99.9 per cent. This type of test is invaluable for determining the continuity of a paint film. Minute



Salt Fog Machine



Weathering Machine

openings in the film will show up when the specimen is subjected to a humidity test.

Science and chemistry, through the engineer, have devised many methods of making accelerated corrosion tests; however, the tests must still be correlated with actual field conditions to be of value in predicting field performance. In addition, the device itself may influence the resistance to corrosion. In order to correlate many of the accelerated tests, the engineer uses outdoor and indoor testing stations. These consist of racks made in such manner to hold specimens at certain angles so that the finish is subjected to the abrasive action of matter propelled by the wind, the ultra-violet and heat of the sun, the ice and snow of winter and washing of rain. Because of the varied atmospheric conditions found, testing stations are located in many areas. The salt atmosphere of the Coasts has a different effect on a finish than the atmosphere in the Middle West. The chemical-laden atmosphere found around a railroad round-house is again different from that found in areas containing high humidity. Close continual study of specimens, often lasting many years, and the correlation of these studies with the results obtained with accelerated tests enables the engineer to predict results of field conditions in days and weeks instead of years. It must be realized, however, that although many thousands of dollars have been used in devising machines for accelerated corrosion tests there is still no one test that will predict field results or guarantee a satisfactory product. The engineer must study and evaluate the results of a number of tests which, in the final analysis, must be combined with experience of the observer and knowledge of the end result of the product.

Bibliography

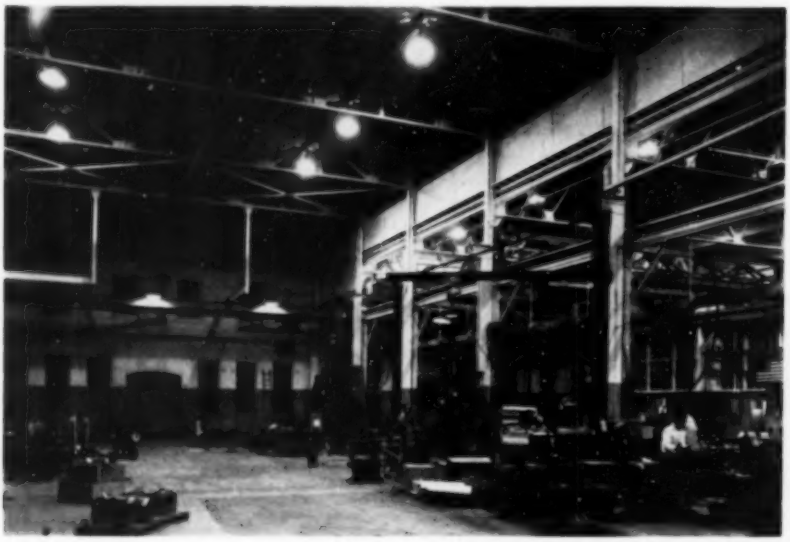
1. "A Manual of Porcelain Enameling." J. E. Hansen, Ferro Enamel Corporation.
2. "Crystleel — How and Where." Benjamin Electric Mfg. Company.
3. The Enamelist — Summer 1949. Ferro Enamel Corporation.

[EDITOR'S NOTE: Similar descriptive articles on the characteristics of other materials used in the lighting industry are planned for future publication. Some of these may include baked enamel, glass, acoustical materials, etc. The Characteristics of Plastics was published in the December 1951 issue.]

High-Bay Mercury Units Used in Industrial Area

The relatively new 1000-watt A-15 mercury lamps are used in this area of the Jackson Church Plant, Saginaw, Mich. The lamps are on 18 x 25 ft. spacings and provide approximately 45 footcandles. Mounting height is 32 feet. The units are installed on disconnect hangers so that they can be lowered to the floor for relamping and cleaning. The generally light finishes reflect light back to the ceiling area, reducing the effect of a black cavern above.

Photo courtesy General Electric Co., Cleveland.



Photographing Lighting Installations

By TOM KNOWLES

A PHOTOGRAPH of an interior is not a scientifically accurate record of the reflected light brightness pattern of the original scene. A picture does, however, present an interpretation of the highlights and shadows. To be completely satisfactory, detail should be retained in the brightest areas of the scene, such as the lighting fixtures, and also in the darker wall or floor surfaces.

Many photographers produce excellent photographs of lighting installations. Each of them has presumably worked out his own methods of appraising the scene characteristics in terms of the final picture making. This paper is intended to help those photographers and lighting specialists who are less familiar with the problem than the professionals.

In general, it is a simpler problem today to obtain good photographs of lighting installations than it was twenty or even ten years ago. In the interest of more comfortable and better seeing conditions, the lighting specialists have exerted much effort. The trend is toward greater visibility through higher illumination with less glare. This means that the brightness range in lighting installations has been reduced.

The manufacturers of photographic films have also made advances in their products which aid the photographer of today. Any fast, long-scale panchromatic film should prove satisfactory in photographing lighting installations. The author used Super XX or Super Panchro press type "B." Average development conditions are 14-17 minutes in D-76 with intermittent agitation. The shorter development period is used for high contrast scenes. The longer development period is used for low contrast scenes.

The sensitivity range of the selected negative film is very high as compared with that of the printing papers. The range of scene brightnesses reproduced on the straight line portion of the sensitometric negative curve is about 1-70. In this range the negative densities will be proportional to the light reflected from the scene elements. However, quite acceptable photographs can be made where scene brightness ranges are as high as several hundred to one. Of course, making of good paper prints from such a contrasty negative calls for special manipulation, such as negative staining and print dodging.

The photographic printing paper must be considered the most important limiting factor when making photographs of lighting installations. Glossy paper is used because of its greater tonal scale, especially in the shadow areas. Its reflectance in the black areas is about 4 per cent. The white area reflects about 78 per cent. This is based on nonspecular illumination at an angle of 45°. The reflectance range of 4 to 78 per cent is a ratio of about 1 to 20.

The most important factors affecting the correct exposure for a photograph are (1) sensitivity, or speed of the film; (2) brightness or the critical shadow area, and (3) lens aperture setting.

By selecting one negative film and processing method, the factor number one can be standardized. Unless people are included in the scene, necessitating relatively short exposure, it is well to standardize on one lens aperture setting. By using a small lens aperture where practical, both foreground and background objects can be in reasonably sharp focus. This leaves only one really important variable factor, the brightness of the critical shadow area.

The brightness of a surface is determined by the light falling on it (incident illumination) and the reflectance of the surface being photographed. In two scenes, both of which indicate the same incident illuminations, the darker colored scene will require a greater exposure. Measurement of the brightness (reflected light) of the darker surfaces of interior scenes requires a relatively sensitive instrument.

Conventional photoelectric exposure meters utilizing reflected light from the scene or its elements are calibrated to fit the brightness range of outdoor daylight scenes. The light values measured in these outdoor scenes are usually far greater than those produced by artificial lighting systems. The illumination of outdoor scenes is generally several hundred times greater than the average indoor illumination. However, the brightness of the luminaires and adjacent light walls and ceiling is usually sufficient to be measured by the reflected light method. The brightness or reflected light from the

*Author: Application Engineering, Lamp Division of General Electric Company, Nela Park, Cleveland, Ohio.

shadow areas would give a meter deflection so small that it could not be measured accurately.

The brightness of the *shadow area* should be considered the most important scene element when determining the exposure of a scene to be photographed. Inasmuch as conventional exposure meters are not sufficiently sensitive to measure the brightness of the shadow area, an indirect approach must be taken. This is done by measuring the incident illumination in the darkest areas in which detail is to be recorded. Incident light is that light falling onto a surface. The meter is held

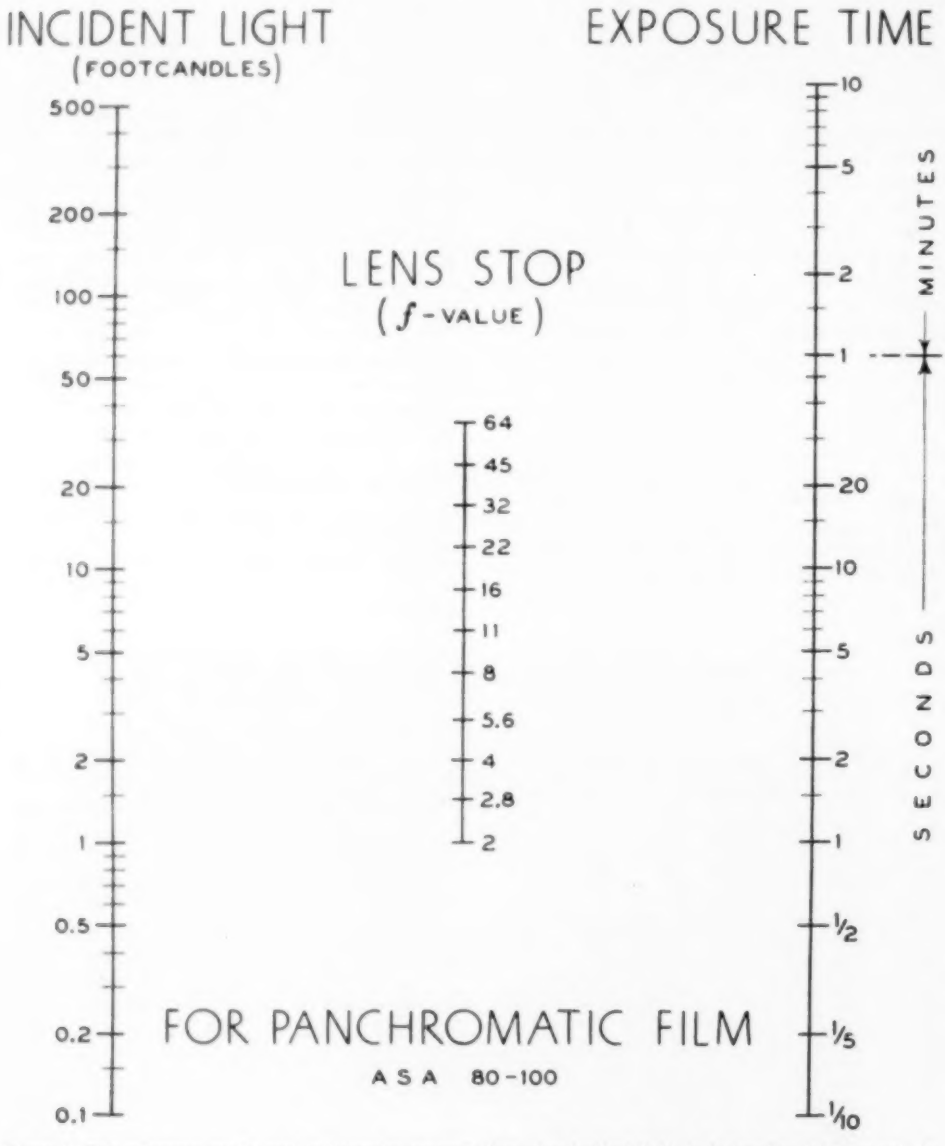


Figure 1. This nomogram can be used to determine exposure time when incident light, in footcandles, is known and the lens stop has been selected. A straightedge placed across the three scales will indicate the proper exposure.

about 18 inches from the floor with the light-sensitive cell toward the camera. Pointing the cell toward the lens is important to avoid underexposed shadow areas. Any meter with sensitivity enough for indoor work should be satisfactory. The author uses a General Electric DW-68 exposure meter. A nomogram (Fig. 1) is provided for the operator using a footcandle meter for exposure determination. If the reflectance of the important shadow areas is midway between very dark and very light, then the exposure should be as indicated by the meter calculator or the nomogram. If the floor and furnishings are quite dark in reflectance, then the exposure should be increased by ½ stop. If the floor and furnishings are lighter than average, the exposure should be reduced by about ½ stop.

When photographing relatively small areas, such as residential scenes, it is practical to use diffuse floodlighting if necessary to soften the shadows. The scene brightness range is explored indirectly by measuring the incident illumination in footcandles; as mentioned before, hold the meter 18 inches from the floor with the cell toward the camera. The illumination at the reading positions near portable lamps, etc., should not be greater than five times that of the floor area reading. If the illumination range is greater than 1 to 5, some degree of diffuse floodlighting is desirable.

In a typical scene with an illumination range of 1 to 12 and a reflectance range of 1 to 5, the brightness range would be the product of these two ranges, namely 1 to 60. The brightness range of this scene must be reduced to somewhere near 20 or 25 to 1 in order to have the negative printable on normal contrast paper. By floodlighting the opposite wall or ceiling area with one or two reflector lamps (75-watt R-30 or 150-watt R-40) or floodlights with appropriate size wattage bulbs, the contrast range of the scene may be reduced. The natural shadows may be softened with the floodlighting but must not be washed out. By adding 3 footcandles of overall soft floodlighting, the illumination range of 2 to 24 will now become 5 to 27 or slightly over 1 to 5. The percentage of light added to the bright areas is relatively small and can be ignored as far as the exposure is concerned.

Figure 2. The illumination from the recessed fluorescent units was quite adequate for taking this photograph. Exposure was four seconds at f/16.

Figure 3. A diffuse flood light reflected from the wall in back of the camera was used to soften the shadows in this scene. Exposure at f/11 was seven seconds.

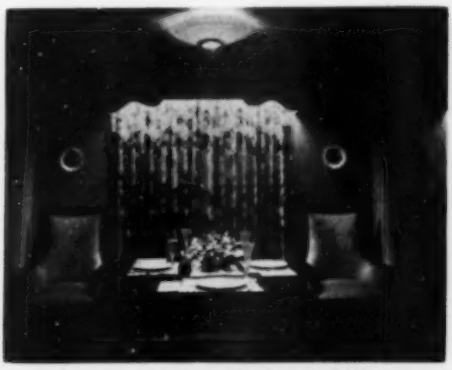


Figure 4. Some diffuse floodlighting is desirable in photographing high contrast scenes of this type and was used here. Exposure at f/16 was forty seconds.

Strong daylight must be avoided as it may wash out the desired lighting effect. It is best to make most residential pictures at night or cover the windows with black cloth from outside the glass, etc. The exposure for this scene is determined by the shadow illumination which has been raised from 2 to 5 footcandles. In this case the exposure is 40 seconds at f32 as read on the calculator of the DW-68 using the "hood off" pointer. If a light meter is used, the same exposure could be read from the nomogram (Fig. 1).

In scenes such as kitchens and hallways, etc., it may be desirable to turn the lighting fixture off part of the time to prevent over-exposure of the fixture. The exposure should be sufficient to establishing the lighting effect produced by the fixture and render the fixture as nearly white on the final paper print. To determine this exposure the fixture brightness can be measured with the DW-68 meter with the hood on. The cover may be open or closed, depending on the brightness measured. If the lighting fixture exposure is made as indicated on the exposure meter, the fixture will not appear lighted. In order that the luminaire will be rendered as nearly white on the print, the exposure indicated should be multiplied by a factor of about 10. If detail is to be retained in the fixture, then the exposure as indicated by the meter may be multiplied by a factor of about 5.

The light meter can also be used to measure brightness by placing the light-sensitive cell against the fixture. A 10 to 1 multiplier mask may be needed to cover the range of brightnesses encountered. To convert light meter readings in footcandles into seconds exposure, use the nomogram (Fig. 1). If the fixture is to be rendered as nearly white, multiply the indicated exposure by a factor of about 1.5. If some detail is to be retained in the fixture, the exposure factor should be approximately 0.7. In cases where the shades are too bright to record desirable pattern detail, it may be necessary to fit a lining of one or more layers of white paper inside the shades.

The photographs of lighting installations in Fig. 2 and 5 were made without the use of supplementary lighting. The exposures were based on the incident footcandle reading. The meter was held about one and one-half feet away from the floor with the light-sensitive cell toward the camera. The photographs in Figs. 6 and 7 were made with the addition of indirect supplementary light. The floodlighting must be reflected from a wall or ceiling to avoid unnatural shadows. It must be sufficient to lighten the naturally dark areas but not so bright that the scene appears floodlighted. It is desirable to make most interior lighting photographs at night-time. When these pictures must be taken during daylight hours the windows must be covered with black cloth or paper.

This system of exposure determination is not intended to reproduce accurately the scene brightness pattern. The system is merely intended to aid the photographer in taking lighting photographs that will convey an acceptable impression of the original scene without introducing lighting effects that are foreign to the scene's actual lighting.

PORTABLE 8-watt fluorescent lamp in a lightweight, tough plastic tube is here used as an accessory for mechanics, when they are working on trucks or cars. *Photo courtesy General Electric Co., Cleveland.*

These Industrial Installations Won Merit Awards

Prize-winning industrial installations in the recent contest conducted by the Fourth International Lighting Exposition, are shown on the following pages. It is interesting to note how closely winning jobs follow the trend in industrial areas toward lighting environments comparable in quality characteristics long accepted for offices.

ONE OF the most important and difficult tasks in flag making is the one which consists in aligning the white stars on the blue field, prior to the sewing operation. The need for accurate alignment is of the greatest importance in turning out a quality product.

Prior to our present lighting solution, the operators used to align the stars by sense of touch, by feeling the stars on the pattern with their fingers. This was a difficult and energy-consuming task. The time element involved and premature fatigue of the workers kept production down. Furthermore, accurate alignment was hard to achieve.

Increasing the lighting level above the table *did not* materially improve the solution of this difficult task. Therefore, an entirely new approach was tried—illumination from underneath the table and making use of brightness differences. The engineering problem involved was to achieve the proper brightness difference between the silhouette of the pattern stars showing through the blue field of the flag and the blue field itself.

The solid table top was replaced with a clear plate glass top. Diffusing paper was attached underneath the glass. Samples of the blue background material used in making flags was tested for transmission of light, as was the transmission of the white material used in the master pattern. With this information, preliminary calculations were made to determine the amount of light necessary under the table to obtain the required brightness differences for easy alignment of the white stars on the blue background. It was felt that a brightness ratio of 3 or 2 to 1 should be achieved to permit easy seeing of the task.

Based on the preliminary calculations, the following equipment was installed:

Lighting over Table: Two industrial type 2-40 watt fluorescent units 3½ feet above table and 8 feet apart.

Under Table: Eight 2-lamp 40-watt fluorescent channels 16 inches apart and 26 inches below glass table top.

This installation resulted in an average illumination value on the table top of 40 footcandles.

Brightnesses were: On blue field of flat—9 footlamberts. On flag field 4 footlamberts.

Brightness Ratios were: Blue field to pattern stars: 90/40 = 2¼.

The size of the table was 4′ 8″ x 16′ 0″. The height of the table from the floor was 35″. The ceiling height of the room was 11′ 0″.

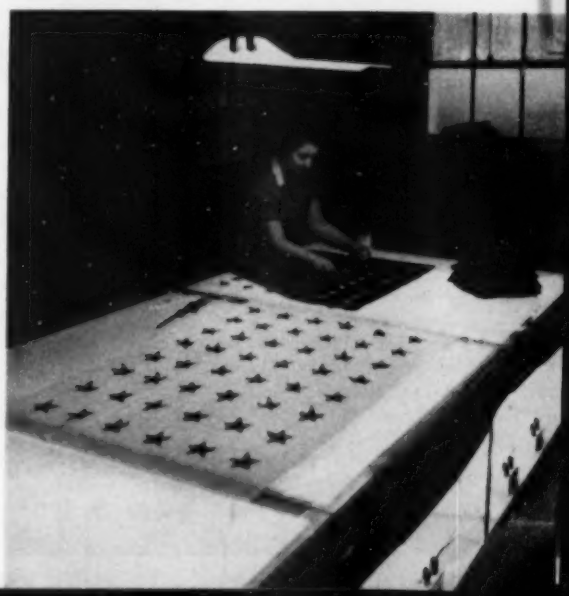
The operation or task now consists of aligning the upper white flag stars with the underneath dark pattern stars, which plainly stand out in silhouette under a brightness ratio of 2¼ to 1. The stars are attached to the field with a thick paste and then sent to the sewing operation.

Since the new lighting was installed, consisting of illumination from below and above, production has increased by 25 to 30 per cent, as attested to by a letter from the Production Manager. Also, better alignment results in a better product.

It is believed that this installation, which utilizes the principle of brightness difference to achieve a successful solution, may point to a new method in solving certain seeing problems in industry.

Editor's note: This installation also took second place in the contest conducted by the New York Section of I.E.S. for "My Most Interesting Lighting Installation."

Merit Award No. 470—Won by F. J. Greenley, Public Service Electric & Gas Co., Orange, N. J. Installation at the Annin Flag Co., Ferona, N. J.



Merit Award With Distinction No. 463—Won by Louis E. Mueller with the late H. P. Howe, Detroit Edison Co., Detroit, Michigan. Installation at the Ludlum Steel Corp., Ferndale, Mich.

Quality industrial lighting, comparable to that advocated for offices, was specifically desired by the customer for this machine shop. They had in mind that experience in this area would serve as a model to guide them in the relighting program for their entire plant.

Careful attention to brightness ratios was included in the plan. Brightness values are: light green wall, 18 ft-L. Yellow wall, 19 ft-L. Floor, 20 ft-L. Ceiling, 33 ft-L.

Equipment featuring a high upward component was used at a 10-foot mounting height. Illumination level at present is 100 footcandles but is expected to maintain at 90 footcandles. Glare factor for this installation is 16.

The problem in this clothing factory was to provide lighting of the proper quality and quantity required for the operation, in a very large area — approximately 1600 square feet. The hand pressers to be located in the area had been working near large windows and the management feared complaints unless lighting values of comparable quantity could be provided.

Equipment employing high upward component in this case 40 per cent up, was installed suspended from the 10-foot ceiling. Illumination averages between 55 and 60 footcandles.

A comfortable seeing environment at these levels was obtained with careful attention to surfaces. Brightness readings are: White ceiling 60 ft-L. Side wall, 20 ft-L. Floor between tables, 15; table tops, 15 ft-L. Fairly dark cloth on the pressing platforms is 15 and light cloth 20 ft-L. The luminaires measure 50 ft-L on the side panels and 120 and 130 ft-L on the louvers.

Merit Award No. 303 — Won by Norman T. Kridel, Rochester Gas & Electric Co., Rochester, N. Y. Installation at the Michael Stern Clothing Factory, Rochester, N. Y.

Merit Award With Distinction No. 397 — Won by George L. Reynolds, Lighting Representative, Public Service Electric and Gas Co., Camden, N. J. Installation at the W. N. Russell Co., Westmont, N. J.

The ceiling of this concrete-form pattern shop was rather low. Since large wooden forms are moved about, hanging fixtures would further aggravate the safety problem and recessed troffers as a solution were readily accepted by management.

Pattern makers perform a rather difficult seeing task requiring high level lighting of good quality. Much of the critical work is done around the perimeter of the shop, and for this reason a greater build-up of illumination levels, of the order of 60 to 70 footcandles, was planned for this area.

Brightness ratios were carefully controlled for a comfortable seeing atmosphere. These values are:

Working surface to wall		1.1 to 1.0
" " "	ceiling	1.0 to 1.7
" " "	floor	1.3 to 1.0
" " "	luminaire	1.0 to 16.7

Ceiling color is flat white, the walls are light grey and the working surface is usually a natural colored, light wood.

Maintenance problems are reduced by having the equipment completely enclosed and recessed in the ceiling.

The three-lamp fixtures are wired so that one, two or three lamps may be switched on at a time, so that three levels of lighting may be obtained when desired.

Merit Award No. 465 — Won by James F. Williams, Dayton Power & Light Co., Dayton, Ohio. Installation at the Standard Register Co., Dayton, Ohio.

The area involved is devoted to the manufacture of marginally-punched continuous business forms, carbon-interleaved. The seeing task is critical in accomplishing fine grade printing, and alignment is of extreme importance. Offset color work as well as other color processes are incorporated in the printing.

Continuous rows of two-lamp luminaires, using 100-watt fluorescent daylight lamps, are mounted 13 feet above the floor on 12-foot spacing center to center. The illumination level is 90 footcandles.

High reflectance surfaces contribute to the seeing comfort achieved. These values are: White ceiling, 75 per cent R.F. White upper wall, 76 per cent. Green dado, 30 per cent and concrete floor of 12 to 15 per cent reflection factor.

Merit Award No. 302—Won by John Kerr, Jr., Public Service Electric & Gas Co., Hackensack, N. J. Installation at Benedict-Miller, Inc., at Lyndhurst, N. J.

Minimum maintenance in this extremely dirty heat treating area, was a major problem. First cost was another. A similar area in this company's old plant was so filled with smoke and grime that a maintenance schedule of cleaning lighting equipment twice a month was required to maintain adequate levels.

The circumstances seemed made to order for R-52 reflector lamps. Eighteen of these, in 750-watt size, are mounted at 25 feet on approximately 16′ by 22′ spacing to produce an average of 29.5 footcandles after 500 hours' operation. The reflectors serve only to protect the lamps from condensation which might drip from the ceiling.

Merit Award No. 418 — Won by Myles McCabe, Central Illinois Public Service Co., Quincy, Illinois. Installation at the Gardner-Denver Co., Quincy, Ill.

Four rows of new distributing-type reflectors using 400-watt AH-1 mercury vapor lamps were added to the two rows of existing incandescent units, in the relighting of this high-bay crane area.

1000-watt lamps are now employed in the older units, to provide some color correction and for lighting during periods when the mercury are might be broken due to a voltage dip.

The incandescent units, of which the old lighting system consisted, are mounted on 19′ 6″ by 30′ centers. One row of mercury units is installed 7′ 9″ to each side of these fixtures. The completed system has reflectors on 7′ 9″ by 19′ 6″ centers over working areas. Spacing over the center area, which is a wide aisle with storage on each side, is 15′ 6″ by 19′ 6″. Average illumination level under the new system is 35 footcandles.

The painting program recommended for improved brightness control had not been completed at the time the photograph was taken. The ceiling has been painted white with 80 per cent R.F. Walls will be repainted to increase the reflection factor from its present 30 per cent, to 60 per cent. Average brightness value of the walls is 2-8 footlamberts; average task brightness is 10.5 footlamberts.

Uniform illumination on both horizontal and vertical surfaces has been obtained with this design, and completion of the repainting program is expected to further improve the seeing environment.

↑ After

Merit Award With Distinction No. 490 — Won by E. M. Wenner, Duquesne Light Co., Pittsburgh, Pa. Installation — Machine Shop.

The industrial plant involved obtained a defense contract which required assembly space not previously available; additional space was also required for the production and assembly of steel machinery. It was recognized that both operations involved close visual tasks and that lighting would be an important factor in the production level, the workmanship and efficiency of the employees.

The space selected for these operations was being used for a foundry. The problem was to convert this area and install lighting for these purposes. It would be necessary to install the lighting fixtures above the cranes involving a mounting height of about 40 feet. In view of this mounting height and the large area, the installation would represent a substantial undertaking to provide the quality and high level of lighting required.

The foundry equipment and facilities were removed and a new concrete floor was installed. Walls, girders, trusses, and the ceiling were cleaned and repainted. The smaller photograph shows the area when it was used for a foundry.

Before

The remodeled and relighted area, shown in the larger photograph includes the installation of 3000-watt mercury vapor lamps in high-bay Alzak aluminum reflectors mounted 41 feet high on 27' by 32' spacing. Average illumination level is 37 foot-candles. For security reasons, the photograph was taken before the installation of war production machinery.

Design Considerations in Lighting an Industrial Plant

By HARVEY R. JUDD

QUALITY has generally not been one of the primary considerations in designing an industrial lighting system. Quantity is always considered but too often the illumination levels selected are inadequate for even the immediate seeing tasks, not to mention the ever increasing demands of tomorrow's accelerated and more complicated production. The industrial lighting described in this article is of interest because of the exceptionally high standards of quality and quantity specified and the unique methods by which those standards were met in the face of the usual and the unusual complications.

The new Convair plant in California is fairly typical except for its size and its assortment of seeing tasks. This plant is being constructed for the U. S. Navy Bureau of Ordnance and will provide facilities for the development and production of Naval Ordnance equipment. The roofed floor area of well over a million square feet is composed of several buildings scattered over a large tract. Seeing tasks range from the calibration of primary instrument standards to ordinary warehousing activities.

With very few exceptions the plant is windowless, the entire active area being air-conditioned. A typical bay is 40 feet by 60 feet with the bottom chord of the trusses at 20 feet. Hung ceilings at 17 feet 6 inches or 10 feet 6 inches appear in some areas. Where no hung ceilings exist the luminaires must be above the bottom chord of the trusses to allow for future bridge cranes. As the plant is located in an area noted for its mild climate it is anticipated that there will be considerable outdoor activity such as storage, testing and possibly some assembly. This activity may well take place at night. Heavily traveled public highways bisect the property and bound it on several sides. The plant will be completely secured, requiring security fencing and 24-hour patrols.

Design Considerations

High levels of illumination were indicated for many tasks such as precision machining, precision assembly, inspection, instrument calibration, drafting and development laboratory work. For these areas, it was felt that a level of 100 footcandles was desired. For some factory areas, 50 footcandles of illumination was selected as adequate. A few areas, such as warehousing, would require only about 15 footcandles.

It seemed advisable to illuminate non-working areas in an entirely different manner from that of the work areas in order to provide a change from the high level illumination and to promote occasional relaxation. Corridors and lobbies are used occasionally by everyone and are found to be excellent places to provide a general change in mood. A short walk or a chat with an associate in the corridor can provide valuable rest if the surroundings are pleasant and relaxing. The cafeterias should be softly lighted and perhaps enlivened with color and music.

Brightness contrast control was considered very important in designing a high quality illuminating system. Even in the factory and laboratories every means must be employed to reduce fatiguing sharp contrast between light source and ceiling, work surfaces and floors, work and table tops, etc.

An experience of the author's regarding contrast may be of interest here. A large industrial area was converted to drafting space with the lighting remaining as it was. Continuous rows of closed-top industrial fluorescents were hung at 10 feet on about 7-foot centers. The illumination level was adequate, about 85 footcandles. Precision drafting was undertaken in this area and the complaints started coming in. Investigation disclosed excessive contrast between the lamps and the dark ceiling above. The other contrasts within the room were good. The ceiling was subsequently lighted by reflector lamps mounted base down atop the existing luminaires. Only a 15 per cent increase in illumination resulted but the effect on the draftsmen was immediate and amazingly favorable. The ceiling (and the gloom) were "lifted," complaints ceased, and even a favorable comment or two was received.

Reflected and direct glare must be kept within reasonable limits. The computer and instrumentation areas where specular reflection and vertical

Author: Consulting Electrical Engineer, Consolidated Vultee Aircraft Corp. (Convair), Guided Missile Division.

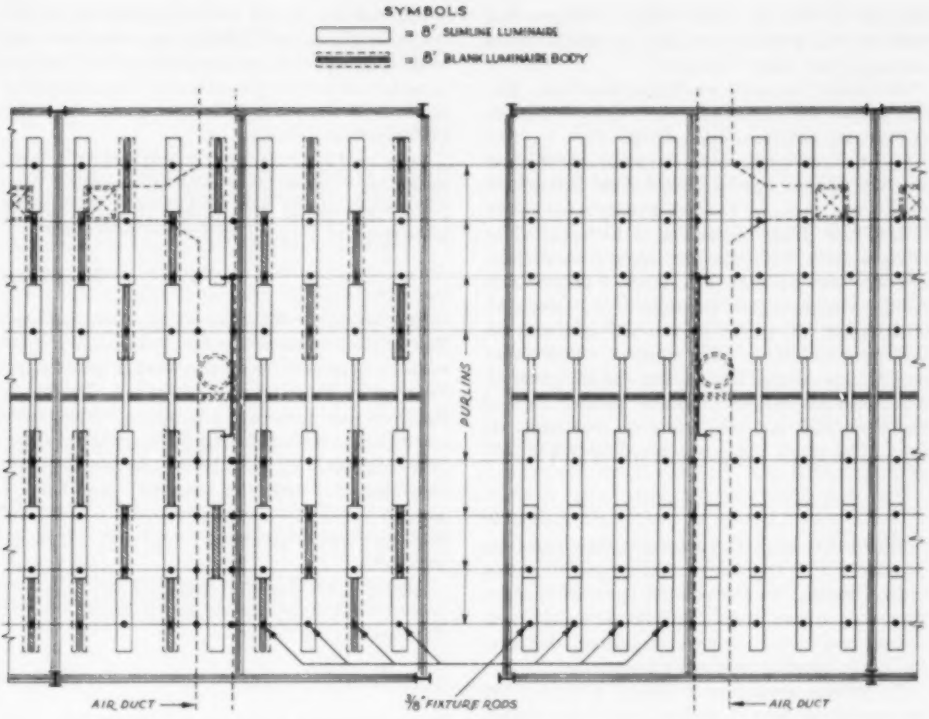


Figure 1.

light are special problems require individual consideration.

The heat load contributed by any illumination system providing the high lighting levels desired was of considerable concern to the air conditioning engineers. Inasmuch as this entire plant is air-conditioned, the efficiency of the lighting system is very important.

Power cost for the operation of such a large, high level lighting system is of course another important consideration. With the possibility of 24-hour operation the lamp and luminaire photometric efficiencies are doubly important.

Most of the luminaires at this plant are mounted 20 feet above the floor. Uniform maintenance procedures for most areas and types of luminaires were desirable, with luminaires capable of being economically lamped on a group replacement basis being specified. Variation of lamp types and sizes were reduced to a minimum. A critical materials situation required that items such as steel and copper used in the lighting system be kept to a minimum. A very tight time schedule made it imperative that the luminaires, wiring materials, hangers, etc. selected be readily obtainable. There was no time for special designs requiring extra days for fabrication or installations.

As public money was being used on this project it was doubly important that an attractive and efficient illumination system be installed with the cost kept at a comparatively moderate figure.

Luminaire Design

To meet these design considerations — the illumination levels outlined, quality of illumination desired, maintenance features, cost and availability — specifications for luminaire design included at least a 6 per cent upward component, two-lamp design for efficiency and distribution, slimline 96T12 lamps. In order to simplify relamping, and to insure lampholder alignment a metalclad duplex or "turret" type lampholder was specified. Standard 5-inch lamp spacing was used.

A baked enamel finish for the reflector was specified to meet considerations of initial cost, light weight, and available steels. The plant will be exceptionally clean and it is felt painted reflectors will give adequate service. Fixture bodies are

crimped to take a simple sliding hanger and couplers were provided to join the bodies into a continuous full width wireway.

The entire luminaire was painted white to further reduce the contrast between top and bottom, and between luminaire and ceiling.

In line with good power practice the highest practical voltage was specified for the ballast primary. The State of California Electrical Safety Orders now allow luminaires to be operated at voltages up to 300 volts with certain restrictions. For this job 277 volts was selected because this voltage was available throughout the plant by bringing out the power transformer neutrals. No lighting transformers were required, which meant considerable savings in cost and critical material. Additional savings were possible because wire of less than half the size ordinarily required was used. The entire plant was wired with #12 TW wire.

Layout

Practically all partitions used in this plant are movable. All departments are subject to being shifted around to accommodate process changes. Therefore, it was decided to provide transformer, panels, and wiring capacity throughout the plant for an illumination level of 90 footcandles.

To provide maximum flexibility a typical bay has continuous rows of luminaires on 6-foot centers. The bottoms of the reflectors are flush with the bottom chord of the truss allowing for future bridge cranes just below the trusses. The trusses and struts affected the exact layout. Where only 45 footcandles are required, the blank fixture body with a cover and no reflector or components is used for alternate units. This allows easy conversion to 90 footcandles by the simple addition of ballast, lampholders, reflector and lamps. All holes, clips, etc., are included in the blank body and the wiring capacity is provided for the future luminaire.

The rigid backbone of the rows made up by the fixture bodies and couplers allows hangers at intervals of 6 feet, which is the roof purlin spacing. It was found that blank bodies could be used in 45 footcandle areas between luminaires at less cost than a rigid channel, and the additional flexibility mentioned above was obtained. Solid rod hangers, $\frac{3}{8}$-inch diameter, support the rows from a clevis and welded stud at each purlin.

The luminaires and arrangement mentioned above were used everywhere except in office areas. Minor changes were necessary where hung ceilings exist but the general pattern is the same. Some areas could well have had a little different luminaire with more up-light and shielding of the lamps, but due to the mounting heights and the desire for maximum flexibility, the industrials were used. Louvers may be required in the drafting areas but may readily be attached to the industrial units. A 45° layout in drafting areas was discarded in favor of uniformity.

Local switching by bays is provided by remote, momentary-contact push buttons operating magnetic, mechanically held contactors in the lighting panelboard at the load center unit substations.

Office Areas

The layout in the office areas is conventional. The luminaires are suspended 12 inches below the ceilings to provide uniform ceiling brightness, yet keeping the fixtures up out of the line of sight. In line with the emphasis on contrast, a luminaire was selected that provides about 50% up-light. Miniature canopies ($1\frac{1}{2}$" x $\frac{3}{8}$") were possible due to the mounting of the junction boxes on top of the ceiling grid, with the cover facing up. Where the higher voltage ballast was used relay switching was provided.

Corridors and lobbies will be illuminated by flush incandescent down lighting providing the low level "change of pace" desired.

Special Areas

An instrument calibration laboratory and a computer laboratory both required considerable light in the vertical plane and a minimum of reflected glare. A corrugated plastic ceiling is being installed, transilluminated by 8-foot slimline fluorescents. About 100 footcandles will be provided on the horizontal plane. Specular reflections will be reduced to a minimum because of the very large light source and overall high level of illumination.

Yard and Security Lighting

To provide night-time illumination on the roadways within the plant and for various outdoor activities, about 1 to 2 footcandles are being provided, from street lighting luminaires. Mercury vapor 400-watt lamps and luminaires with Type III refractors were used. The ballast for building mounted luminaires are on a 480-volt multiple circuit and pole mounted luminaires are on a series circuit with the RO transformers in vaults.

Security lighting where the fence is along a public street is also by street lighting luminaires. This arrangement provides a modification of the glare projection system of security lighting. Isolated boundaries are lighted by Fresnel units mounted on poles about 6 feet inside the security

fence. In every case the guards patrolling the inside of the fence will be in a relatively advantageous position from a glare and illumination level standpoint.

Conclusions

Quality in industrial lighting, as judged by good commercial standards, is possible at little or no extra cost by careful selection of the light source and the luminaire, and by good layout design.

Always let some light up to illuminate the ceiling; 20 per cent is better than the 6 per cent used here but of course it lowers the utilization factor of the luminaire. A little light on the ceiling may well be the difference between a good job and a poor one.

Keep the ceilings and luminaires white. White paint for ceilings is available with a reflection factor of 87 per cent. Follow the accepted minimums for reflection factors — ceilings 75 per cent, walls 50 per cent, floors 35 per cent. Floors and furniture play a big part in lighting the ceiling by reflected light.

On big jobs standardize on lamps and ballasts to reduce maintenance costs.

For economy and flexibility use continuous rows of luminaires or alternate luminaires and blank bodies.

Write complete, detailed and rigid specifications. Avoid calling out a specific make. Decide what you want in distribution, upward component, overall efficiency, quality and finish and spell it out. The bidder will know exactly what you want and you will get it at a reasonable price.

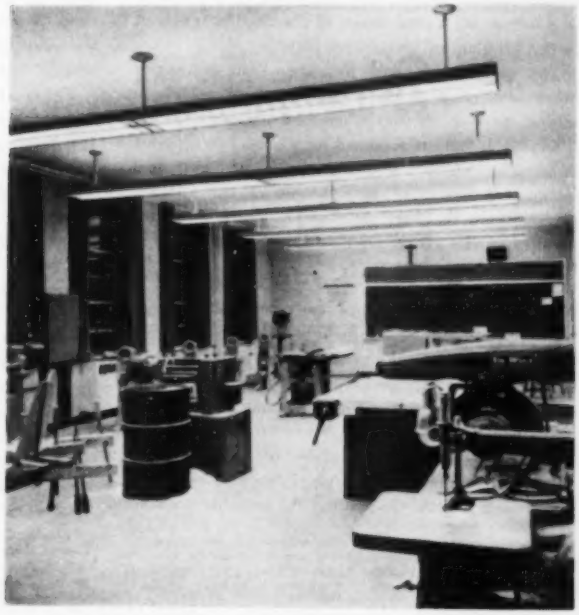
Plan ahead for higher levels of illumination. The product keeps getting smaller and the pace keeps getting faster. Illumination levels of 100 footcandles will be as common in a few years as 35 is now. Make layouts that can be easily expanded and provide 100 per cent excess capacity in transformers, panels and wiring.

Plan for general illumination levels of sufficient magnitude for the task without the use of supplemental lighting.

For really tough jobs, local spot lighting, grazing light or transilluminated panels can then be used with comfort. There is a very comfortable 250-footcandle job in a large room at an eastern laboratory; 100 footcandles will be commonplace — and comfortable — at the industrial plant about which this article was written.

Louvered Lighting For Woodworking Shop

School authorities of St. Edward's High School, Lakewood, Ohio, intended that the seeing environment of the wood working shop should be equal to that of other classrooms, realizing that accurate seeing is important for operating power machinery. Room surfaces have been finished in light shades with light finishes on machines and benches, where they were available. Two-lamp 96T12 louvered luminaires with a component of upward light were selected. The 16-foot rows are on 8-foot centers. Illumination is about 40 footcandles, maintained. ***Photo courtesy General Electric Co., Cleveland, Ohio.***



Oculomotric Muscle Forces And Fatigue

By KURT S. LION

This paper is a summary of the I.E.S. Research Fund Project No. 5, "Measurement of Work Done by Extrinsic Ocular Muscles." Experiments using the method of measurement developed indicate no change in eye muscle force or speed of eye movement after a strenuous visual task even though the subject felt fatigued.

The Problem

A GREAT variety of methods has been employed in the study of vision and in research on the effects of lighting on seeing. Today it is generally realized that visual acuity tests are not sufficient; and various attempts have been made to obtain a quantitative measure of "visual fatigue" and "visual comfort."

Visual fatigue has frequently been used as a criterion for the performance of the eye. While fatigue of muscles can be defined generally as a decrement in muscular output (force or power), and is accessible to physical measurements with ergometers, this is not so in the case of visual fatigue. Visual fatigue seems to be rather a pattern composed from different associated phenomena.[1]

When in 1946 Moon[2] expressed the opinion that visual fatigue may be merely a fatigue of the oculomotric muscles, it seemed very hopeful to attack the old problem in a new way, namely by objective physical, ergometric measurements. Such measurements seemed also particularly interesting as a means for a separation of the factors involved in the problem of vision and fatigue.

The present research indicates that ordinarily *there is no such thing as fatigue of the extrinsic ocular muscles.* Nevertheless, this research points a way to better understanding of the influence of lighting on vision. It also suggests how electrical instrumentation may be valuable in the further investigation of illumination level, glare, and uniformity of the visual field.

Method and Results

It is impossible to apply any one of the conventional ergometric methods to the measurements on the extrinsic ocular muscles. Even the application of wire strain gauges would only be possible in animal experiments. The following method[3] was developed therefore:

If one applies to the temples of a subject two electrodes connected to an amplifier and recorder, one obtains a graph indicating the angular position of the eyeball at any time during the experiment (Fig. 1). Differentiation of this graph furnishes the velocity of the eyeball at any time. A second differentiation gives the acceleration. Since inertial force is equal to mass times acceleration,* the muscular force at any time can be read from the acceleration graph. Rather than to differentiate these records graphically (which would be an impossible task for any greater length of the experiment) the output from the amplifier is led to a differentiating network and then recorded. Repeated differentiation by a second similar network leads to a record showing the eyeball acceleration as a function of time. Figure 2 shows the position of the eyeball, the velocity, and the acceleration (A) for reading, and (B) for a motion center-left-center-right.

For a fatigue experiment the subject is seated in a shielded room, the electrodes are connected and two lights are flashed alternatively in front of the subject. The subject is told to fixate the light, and the flashing frequency is increased to the highest speed the subject is able to follow (about 150 times per minute). Movement, velocity, and acceleration are recorded periodically during this test until the subjects are unable to continue any longer.

At the end of the test the subjects either were not able to move their eyes successfully to the mark, or they complained about ocular discomfort, burning, watering, nausea or dizziness. The stress period varied from 4 to 28 minutes with an average of 10 minutes.

The analysis of all records shows that there was no decrease of acceleration of the eyeball and therefore no reduction of the forces of the extrinsic ocular muscles. However, two main variations of

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The complete report (from which this condensation was prepared) was released by the Research Executive Committee and the Trustees through a letter ballot circulated in March 1951.

Author: Department of Biology, Massachusetts Institute of Technology, Cambridge, Mass.

*For the rotatory movement of the eye the mass is to be replaced by the moment of inertia of the eye, the acceleration by the angular acceleration.

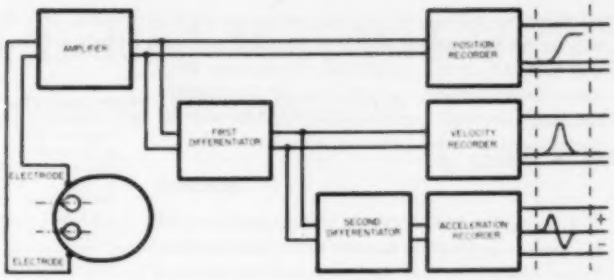


Figure 1. Schematic diagram of the experimental set-up for the recording of oculomotric force. See text.

the original pattern occurred during the stress test: The records show either a decreasing excursion of the eyes (the subject being satisfied with extrafoveal images), or the inability of the subject to move the eyes rhythmically. Apparent "stalling" or "freezing up" or "split" movements were noted. In all tests the ability of the subjects of accurate fixation was restored within twenty to thirty seconds after the termination of the stress test.

Conclusions

The result of these experiments, that the extrinsic ocular muscles do not show fatigue under prolonged stress, while the subject subjectively feels and objectively shows signs of fatigue, is of interest in more than one respect. To understand this phenomenon we must make the following assumption (Fig. 3). Any muscle, when stimulated, performs work. It is well known that it also develops some by-products (chemical, physical, and neurological changes) which act back upon the muscle (feed back loop e) and lead to an attenuation of the measurable muscular force. However, a second feedback loop d relays the status of fatigue also to the motivating center. It is felt as fatigue (or pain) in the central nervous system, and ultimately also diminishes muscular output and force.* The fatigue produced by strain of the extrinsic ocular muscles is, therefore, a fatigue in the central nervous system, and not of the extrinsic eye muscles as such, as has also been shown by Brožek.[1]

What, now, is the influence of the illumination level upon visual fatigue? One path of influence obviously affects through the "servomechanism linkages" f and g, the contraction of the iris, diminishing the numerical aperture of the eye at higher levels of illumination. The physical consequence of a smaller aperture is an increase in depth focus, and therefore a reduced need for the intrinsic ocular muscles to accommodate.

But it is highly suggested that a second link h relays the level of illumination as an environmen-

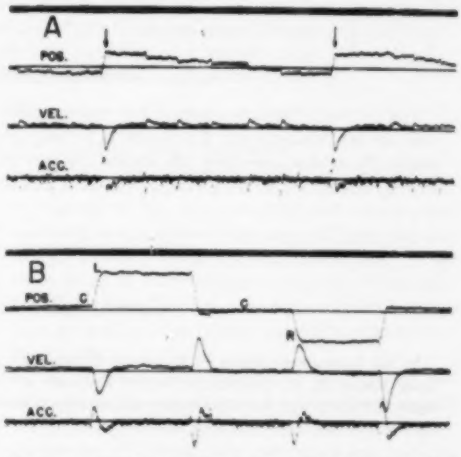


Figure 2. Position velocity and acceleration (muscular force) record of the eyeball. A, during reading (return sweep at arrow). B, during a motion of the eyes center-left (C-L), center-right (C-R).

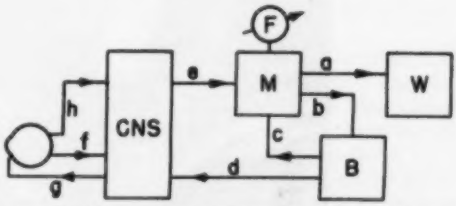


Figure 3. Schematic diagram showing the interaction of the biophysical elements involved in a visual task. M, muscle; W, work output; B, by-products (see text); CNS, central nervous system; F, ergometer measuring muscular force; a to h, connecting links.

*This is the general case of a muscle (*e.g.* biceps). In the case of the extrinsic ocular muscles the picture is somewhat more complicated, since these muscles lack proprioception. The feeling of unpleasantness in this case must be produced in the central nervous system through the continuous variation of the conceived visual impression. With this modification the picture of Fig. 3 is also applicable to the extrinsic eye muscles.

tal factor to the central nervous system in such a way as to increase and decrease the level of "central fatigue." If this should prove to be true, there would be an influence of the level of illumination not only for visual performances, but also for the performance of other, non visual tasks.

Summary

A method is described for the measurement of the forces exercised by the extrinsic ocular muscles. These muscles do not show a decrement of force (fatigue) under stress tests. Visual fatigue therefore must arise in the intrinsic ocular muscles and (or) in the central nervous system.

Acknowledgment

The author wishes to express his sincere gratitude to the Illuminating Engineering Society Research Fund for providing the means for this research, and to Mr. E. R. Powsner, Dr. R. J. Brockhurst, Mr. W. R. Pearce and Mrs. J. Kaslow for their collaboration and valuable help.

References

1. Extensive literature references may be found in
L. Carmichael and W. F. Dearborn: *Reading and Visual Fatigue*, Houghton Mifflin Company; 1947, Cambridge.
M. Luckiesh and F. K. Moss: *Reading as a Visual Task*, D. Van Nostrand Co., 1942, New York.

2. E. Marg: "Development of Electro-Oculography," *Archives of Ophthalmology*, 45, #2, p. 169-185, 1951, February.

3. J. Brozek: "Quantitative Criteria of Oculomotor Performance and Fatigue," *Journal of Applied Physiology*, 2, p. 247, 1949.

4. P. Moon: Research Proposal, submitted to the I.E.S. Executive Committee, 1946 (not published).

5. E. R. Powsner and K. S. Lion: "Testing Eye Muscles," *Electronics*, March 1950.

6. Powsner, E. R.: "Experimental Studies of a Technique for the Measurement of the Corneo-Retinal Potential of the Human Eye," thesis submitted in partial fulfillment of requirements for Master of Science degree at Massachusetts Institute of Technology, 1949.

7. Lion, K. S. and Powsner, E. R.: "An Ergographic Method for Testing Ocular Muscles," *Journal of Applied Physiology*, October 1951.

8. Brockhurst, R. J. and Lion, K. S.: "Analysis of Ocular Movements by Means of an Electrical Method," *A.M.A. Archives of Ophthalmology*, September 1951.

9. Lion, K. S. and Brockhurst, R. J.: "Study of Ocular Movements under Stress," *A.M.A. Archives of Ophthalmology*, September 1951.

Comfortable Lighting in a Bakery

In the bakery department of Bickford's Commissary in Long Island, N. Y., continuous rows of two-lamp 96T12 units with open tops and plastic sides are suspended from the 14-foot high ceiling. This installation provides approximately 40 footcandles illumination on the working areas. The important sanitary appearance is enhanced by the white ceiling and walls and red tile floors. Good lighting encourages good housekeeping.

Photo courtesy General Electric Co., Cleveland

The Use of the Luckiesh-Moss Visibility Meter For Prescribing Illumination

By GLENN A. FRY

In the deliberations of the A.P.H.A.*-I.E.S. Task Committee, footcandle standards (their sources and their significance) were studied at some length. It was found that to a large extent recommended footcandle values had evolved from measurements made with the Luckiesh-Moss visibility meter. Consequently the Committee invited Dr. Glenn Fry, one of its members, to present an analysis of the theory and functioning of the meter. The following paper explains the principles involved and presents a new approach, differing from that of the originators of the meter, rationalizing its meaning and use.

E. M. Strong, *Chairman*
A.H.P.A.-I.E.S. Task Committee.

IN PRESCRIBING illumination one is concerned mainly with objects which are not self-luminous and which are observed against a background also not self-luminous. The brightness values of the object and the background are determined by their reflection characteristics and by the quantity of illumination falling on them. The illuminating engineer has to decide what quantity of illumination is desired.

Illumination purposes primarily to promote visibility. But whereas illumination is readily measured in footcandles, the quantitative significance of visibility is controversial and it is yet without dimension or its own unit of measure. This is because it is a function of the human visual mechanism and depends on the necessarily subjective appraisal of a visual task by an observer.

The simplest appraisal of visual tasks is threshold discernment; if the illumination is reduced, a level is finally reached at which the task can no longer be identified. This is the threshold level of illumination—it is that level where discernment of a given visual task begins. (This is somewhat like the boiling point of a steam boiler — a "threshold" of temperature which must be reached before the useful pressure-producing function of the boiler can even begin.)

Clearly, threshold is not a desirable or even a minimum working value of illumination but it does provide a datum from which to reckon illumination in relation to visibility. Any desired illumination can be expressed as a ratio of desired to threshold or as so many log units above threshold. This ratio, or number of log units, although *not a measure* of visibility is an index of the discernability this illumination will provide for the given task. If the ratio is set at 1000 (3 log units), the footcandles for various tasks will vary widely with the task but bear a fixed relation to the respective discernment thresholds.

Now if one specifies the desired level of illumination as being so many log units above the threshold level, then prescribing illumination becomes a simple matter of determining how many log units an existing amount of illumination is above the threshold, and then computing the factor by which this existing illumination must be increased or decreased to bring it to the desired level. Let the number of log units be designated by the symbol U (for units).

Suppose for a given task the desired value of U is 2.5, and the measured value of U is 1. Then by deducting 1 from 2.5 we find that the illumination must be increased 1.5 log units, that is to say, it must be increased by a factor equal to $10^{1.5}$.

A device like the Luckiesh-Moss visibility meter can be used to determine the value of U for a given object under a given amount of illumination.

The essential element of the Luckiesh-Moss visibility meter is a pair of circular photographic wedges through which the respective two eyes of the operator view an object. These two filters are matched and rotate in unison so that the two eyes look through corresponding portions of the two filters. When the wedges rotate in a counter-clockwise direction, the portion interposed causes the object to become more difficult to see. The wedges

Author: School of Optometry, The Ohio State University, Columbus, Ohio.

*American Public Health Association.

are rotated until the object appears to reach the threshold of visibility. From the optical properties of the wedges one can compute the number of log units which the existing illumination is above the threshold, and the wedges can be calibrated accordingly.

How the Meter Reduces an Object to the Threshold of Visibility

In order to understand how the visibility meter works, it is necessary to analyze the manner in which the filter affects for the observer the appearance of the brightness B of the background and the contrast C between the object and the background. The object and the background constitute two areas adjoining each other at a contrast border. For the purpose of making this analysis, the following symbols may be used:

E = illumination

r = reflection factor of the darker of the contrasting areas

R = reflection factor of the brighter of the contrasting areas

$b = Er$ = brightness of the darker of the contrasting areas

$B = ER$ = brightness of the brighter of the contrasting areas

$C = \dfrac{B - b}{B}$ = contrast

α = transmision factor for the filter

β = veiling brightness factor for the filter

b' = brightness of the darker area

B' = brightness of the brighter area

$C' = \dfrac{B' - b'}{B'}$ = contrast

} seen through the filter when the filter is set to give the threshold of visibility

Because the filter is made of a light-transmitting material which both absorbs and diffuses, the apparent brightness of a surface seen through the filter is composed of two components:

1. Brightness b' which is a fraction α of the surface brightness b, the value of α depending on the density of the wedge.
2. Brightness β which is generated by the diffusion of light transmitted by the wedge, according to the density of the wedge and the light (illumination) reaching the wedge.

Considering two brightnesses, b of an object and B of its background, we find apparent brightnesses b' and B' as follows:

$$b' = \alpha b + \beta, \qquad (1)$$

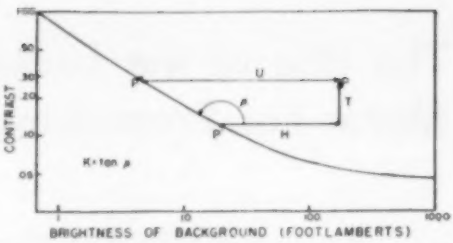


Figure 1. Principles involved in the measurement of U with the Luckiesh-Moss visibility meter.

and

$$B' = \alpha B + \beta = B\left(\alpha + \frac{\beta}{B}\right). \qquad (2)$$

The contrast (C') seen through the filter is given by the following equation:

$$C' = \frac{B' - b'}{B'} = \frac{B - b}{B} \cdot \frac{\alpha}{\alpha + \frac{\beta}{B}} = C\,\frac{\alpha}{\alpha + \frac{\beta}{B}}. \qquad (3)$$

In the case of a pattern like a grating consisting of alternate bright and dark bars of equal width, there is no way for deciding what constitutes object and what constitutes background. As a matter of fact, it makes no difference whether the bright bars are regarded as objects and the dark bars as background, or vice versa.

The Threshold Curve

Objects having the same size and configuration and the same type of contrast (i.e., bright on dark, or dark on bright), but having various combinations of values for r and R, will require different levels of illumination for the threshold. If these objects at the threshold of illumination are represented on a plot of log C against log B, as shown in Fig. 1, the locus of the points representing these objects will form a curve which is called the *threshold curve* for objects of the given size, configuration, and type of contrast.

Measurement of Suprathreshold Levels

Let us select any one of these objects which is sufficiently illuminated to bring it to a suprathreshold level of visibility. It can be represented on the graph by the point P which has coordinates C and B corresponding to the contrast of the object with its background and the brightness of the background.

If the visibility meter is used to bring the object to its threshold, the object seen through the meter can then be represented by a point P' on the threshold curve having coordinates C' and B'.

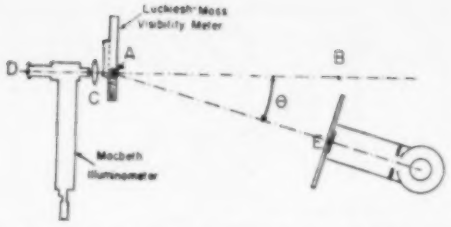


Figure 2. Experimental arrangement for measuring the optical properties of the gradient filters.

The lateral displacement (H) of P from P' is given by the following equation:

$$H = \log B - \log B' = \log \frac{B}{B'} = \log \frac{1}{x + \frac{\beta}{B}}. \quad (4)$$

The vertical displacement (T) of P from P' is given by the following equation:

$$T = \log C - \log C' = \log \frac{C}{C'} = \log \frac{x + \frac{\beta}{B}}{x}. \quad (5)$$

Instead of using the visibility meter to reduce the object to its threshold, let us do it by varying the illumination. If we use the symbol E to represent illumination and r and R to represent the reflection factors of the contrasting areas,

$$B = ER,$$

and

$$C = \frac{R - r}{R}.$$

The contrast is constant but reducing the illumination (E) reduces the value of B in the same proportion. In terms of Fig. 1 the lateral separation (U) of P from P' represents the number of log units that the illumination has to be reduced to bring the object to its threshold of visibility. It also represents the number of log units above the threshold of visibility represented by the point P.

It can be seen now how the visibility meter can be used to measure U because U bears the following relation to H and T as shown in Fig. 1:

$$U = H - \frac{1}{K} T = \log \frac{1}{x + \frac{\beta}{B}} - \frac{1}{K} \log \frac{x + \frac{\beta}{B}}{x}$$

$$= \frac{1}{K} \log x - \left(1 + \frac{1}{K}\right) \log \left(x + \frac{\beta}{B}\right). \quad (6)$$

where K is the slope of the threshold line at the point P'.

If K can be treated as a constant and if the ratio $\frac{\beta}{B}$ can be treated as having only one value for each part of the filter, then the rotating filter can be calibrated directly in terms of U.

It remains now to determine what values ought to be assigned to K and $\frac{\beta}{B}$ for different parts of the filter, and also to what extent deviations from these assigned values will affect the measurement of U.

An Exact Equation for β

As pointed out above, β is dependent not only on the density of the filter but also upon the distribution of brightness in the field of view.

In order to investigate the effect of the brightness distribution, the following measurements were made. The experimental arrangement is shown in Fig. 2. The visibility meter and the Macbeth illuminometer were mounted rigidly on a rotating table which permits them both to rotate around a point A which lies in the plane of the filter. The regular exit pupil of the illuminometer was exchanged for a special exit pupil consisting of a slit 2.5 mm long and 0.5 mm wide. The lens at C produces an image of this exit pupil (D) at the point B. The source at E is a rectangular luminous surface 32 mm high and 15 mm wide, located 1150 mm from A, and having a brightness of 13,900 foot-lamberts. If the unit consisting of the visibility

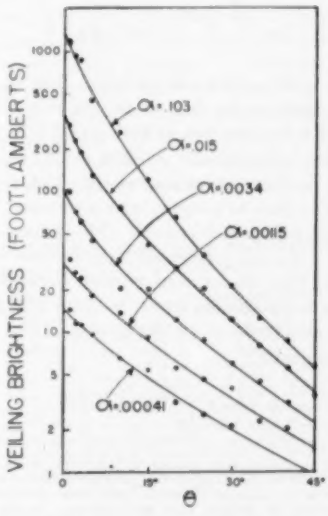


Figure 3. Relationship between β and θ for various settings of the filter.

meter, the illuminometer, and the lens at C is pointed directly at the source E, one can measure the brightness (B_1) of the source at E through the filter and then the meter can be removed and a determination of the brightness (B_2) without the filter can be made. The ratio B_1/B_2 gives the value of α for the portion of the filter through which the measurement of B_1 is made.

When the unit consisting of the visibility meter, the lens C, and the illuminometer is pointed in a direction which makes an angle θ from the center of the source E, the source E becomes a glare source and one can measure the veiling brightness, β. The values obtained for β for different values of θ and for different portions of the filter are shown in Fig. 3. The data have been extrapolated to determine the values of β for $\theta = 0$.

These measurements make it possible to determine the value of the veiling brightness β for the complete brightness distribution in the field of view of the instrument regardless of what the brightness distribution may be. Since one knows the area and brightness of the glare source E, and the solid angle which it subtends at A, as well as the value of β for each value of θ, one can compute for each value of θ the value of ψ, which represents the veiling brightness per unit of brightness of the glare source per unit solid angle. The general equation for the total amount of veiling brightness (β) at A produced by the whole distribution of brightness in the field of view is given by the following equation:

$$\beta = \int_0^{\frac{\pi}{2}} \int_0^{2\pi} \psi \, B \sin\theta \, d\phi \, d\theta, \qquad (7)$$

where ϕ is the meridional deviation from the zero half meridian of the field of view, ψ is a function of θ, and β is a function of both ϕ and θ.

We can simplify the problem by mounting a hood on the front of the instrument which restricts the field of view to a region with a circular* boundary subtending 10 degrees or .1745 radians at the point A. We can further simplify the problem by assuming that the exposed portion of the field is uniform in brightness which is equal, say, to the average brightness and is designated by S.

Consequently,

$$\beta = 2\pi S \int_0^{.087} \psi \sin\theta \, d\theta. \qquad (8)$$

* A hood with a rectangular opening ⅝ inch x 2¼ inches about 3 inches in front of the front surface of the instrument has been recommended by Luckiesh, Eastman, and Guth (ILLUMINATING ENGINEERING, Vol. XLIII, 1948, pp. 223-230). In the vertical direction this would subtend about 10 degrees at the point A. This permits binocular observation. Circular apertures such as described above would not be practical unless observation were confined to one eye.

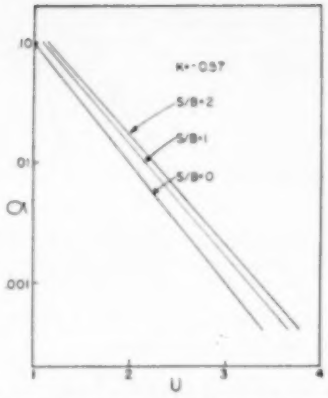


Figure 4. The effect of the variations in the ratio (S/B) on the relationship between U and α.

Since $2\pi \int_0^{.087} \psi \sin\theta \, d\theta$ is a constant for a given portion of the filter, let us define

$$\gamma = 2\pi \int_0^{.087} \psi \sin\theta \, d\theta. \qquad (9)$$

Hence,

$$\beta = \gamma S. \qquad (10)$$

Values of γ have been computed for various parts of the filter, and the results are presented in Table I.

Since,

$$\frac{\beta}{B} = \gamma \frac{S}{B},$$

the ratio, $\frac{S}{B}$, must be constant in order for $\frac{\beta}{B}$ to be constant for a given portion of the filter. The most frequently encountered situation is one in which the average brightness S of the 10-degree field surrounding the critical object is equal to B, which is the brightness of the immediate background of the object.

It is recommended, therefore, that a value of 1 be assigned to $\frac{S}{B}$ for the purpose of calibrating the instrument. Fig. 4 shows the effect of varying the value of $\frac{S}{B}$ on the calibration curve.

The introduction of any non-uniformity into the field, including glare sources, can be treated as a change in the value of S. This is illustrated well by the special case in which the whole field of view is a grating consisting of alternate dark and bright bars of equal width. If B represents the brightness of the bright bars and b the brightness of the dark

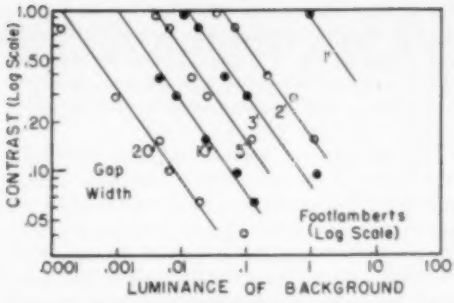


Figure 5. The Connor-Ganoung threshold data, *J. Opt. Soc. Am.*, 25, 287-294 (1935) for Landolt C's of various sizes. The original data of Connor and Ganoung were presented as curves on a plot of log size against log illumination. The original data therefore had to be interpolated in order to produce the above graph.

bars, it is obvious that in this case S is equal to $(B + b)/2$.

Effect of Variations in K

As explained above, K represents the slope of the threshold curve at the point P'. Fig. 5 shows threshold curves for Landolt C test objects of various size mounted at the center of a uniformly bright field. The threshold data for contrast levels between 0.2 and 1 can be fit reasonably well with straight lines having a slope of -0.57, and for this reason the value of -0.57 can be used in calibrating the visibility meter.

Although K appears from the set of data in Fig. 5 to be reasonably stable for the type of test objects and levels of contrast represented, variations in K can certainly be expected. Fig. 6 shows the effect of varying K on the relation between U and a.

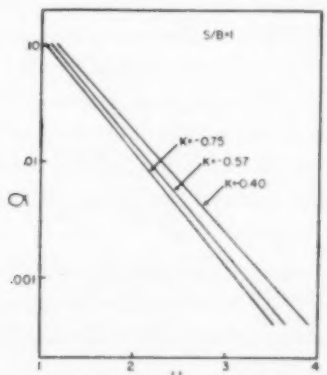


Figure 6. The effect of variations in K upon the relationship between U and a.

As shown in Fig. 1 the slope of the threshold curve decreases as the contrast drops, and since it is not practical to make allowance for variations in K, the use of the visibility meter for measuring U becomes less and less exact as the lower levels of contrast are approached.

Compensation for Differences Between Individual Observers

In order to correct a given observer's visibility meter readings expressed in terms of U so that they will correspond to those for a standard observer, the observer could measure the threshold of a specimen of 8-point Bodoni Book type under the same level of illumination as the task in question and then determine from a chart the reading for a standard observer at the same level of illumination. The difference (the personal allowance) deducted from (or added to as the case may be) his own reading for the task in question should give a reading that approximates the reading for the standard observer.

The Adaptation of the Observer

When the operator looks through the filters to measure the visibility of an object, the filter reduces the brightness level of the object and its background and surround to a much lower level than that to which the eyes are adapted. Sufficient time must be allowed, therefore, in making the measurement to permit the eyes to become adapted to this lower level. Fortunately, the measurement depends upon foveal vision and 2 to 3 minutes suffice to give stable readings. To overcome this difficulty, the operator should increase the density of the filter until the object becomes invisible and make his settings by bringing the object from invisibility to visibility. These readings should be repeated until they become stable.

TABLE I.—Data for the Visibility Meter.

Relative Visibility*	a	γ	U Calculated from Equation (6)**	U Measured Directly***
1	.10300	.0323	1.08	.60
2	.01510	.0068	1.95	2.19
4	.00340	.0025	2.64	3.08
8	.00115	.0010	3.13	3.62
16	.00041	.0005	3.67	3.97

*Relative Visibility is one of the scales marked on the visibility meter which can be used to identify the portions of the filter for which the values of a and γ are specified.

**In making these calculations, it was assumed that $\beta/B = \gamma(S/B)$, that $S/B = 1$, and that $K = -.057$.

***Luckiesh, M., Guth, S. K., and Eastman, A. A.: "A New Scale of Relative Footcandles for the Luckiesh-Moss Visibility Meter," Illuminating Engineering, Vol. XLV, No. 4, p. 211 (April 1950).

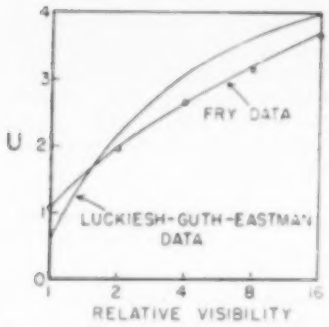


Figure 7. Relationship between relative visibility and the number of log units (*U*) above the threshold. Fry's *U* values have been computed from the scattering and absorption characteristics of the filters, and assume a pupil of constant size and a 10-degree field. The Luckiesh-Guth-Eastman data are based on direct measurement with the natural pupils of the threshold of illumination for 8-point Bodoni type on an unrestricted bright background both without the meter and through different parts of the filters.

The Use of Artificial Pupils

If observation were restricted to one eye, an artificial pupil, perhaps one 2 mm in diameter, could be used. This would eliminate one of the factors that cause variation from observer to observer.

The use of an artificial pupil would affect not only the shape of the threshold curve in Fig. 1 but would also displace it to the right. Hence the recommended level would have to be a smaller number of log units above the threshold. If the principle of a fixed number of log units above the threshold level is used and if an artificial pupil is used instead of the natural pupil, the effect would be to prescribe relatively higher levels of illumination for hard to see objects as compared with easy to see objects.

Direct Calibration of the Meter

Luckiesh, Guth, and Eastman[1] have described a method for calibrating the visibility meter in terms of the number of log units above the threshold level. Essentially their method consists in determining first of all the threshold level of illumination for 8-point Bodoni type on a uniform background, and then determining the threshold level of illumination for the same target observed through different portions of the filters. The values they have given as representing data for a normal observer are shown in columns 1 and 5 of Table I. They have also given 0.01 footcandles as the threshold level of illumination when the 8-point Bodoni type is observed without the meter. These data are plotted in Fig. 7. Plotted also in the same figure are the corresponding data based on measurements made with the illuminometer and shown in column 3 of Table I.

The discrepancy between the two calibration curves can be accounted for on two bases. On the one hand, the theoretical data are based on the assumption that the field is restricted to a 10-degree region, whereas the field of view in the case of the measurements made by Luckiesh, Guth, and Eastman was limited to a rectangular opening subtending a visual angle of approximately 10 degrees by 45 degrees. In the second place, variations in pupil size are involved in the direct measurements, and this would account for the greater curvature of the calibration curve based on direct measurements. If an artificial pupil had been used and if the field had been restricted to 10 degrees for the direct measurements, one would expect that identical sets of data would have been obtained.

Reference

1. Luckiesh, M., Guth, S. K., and Eastman, A. A.: "A New Scale of Relative Footcandles for the Luckiesh-Moss Visibility Meter," ILLUMINATING ENGINEERING, Vol. XLV, No. 4, p. 211 (April 1950).

Home Lighting Data Packet Is Available

The latest packet of Home Lighting Data Sheets, including Data Sheets 22-20 through 22-29, is still available. Referred to as Home Lighting Packet #2, the installations covered include lighting for a Glass Block Window, a Window Wall and Terrace, a Den, a Dining-Room, an Apartment Bedroom, a Hallway, an Apartment Living Room; also Decorative Lighting Effects, Mirror Lighting Applications and Soffit Lighting of a Kitchen.

Home Lighting Packet #2 is available at 50c from Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

The Photometry of Projected Light

By J. M. WALDRAM

This report* was prepared as Part 6 of a proposed compendium on signal lighting being assembled by the I.E.S. Committee on Elements of Signal Lighting. The plan is to publish the parts as they are released. It is hoped that the collected parts will be available ultimately under the title "Elements of Signal Lighting."**

6.1 — *Introduction: The Required Accuracy of Measurement* — A discussion of methods of measurement of the properties of a piece of equipment must begin by considering the precision required of the results, which leads to the consideration of the purpose of the equipment, the tolerance permitted in its performance, and the relationship between the performance and the property measured.

Projection equipment used in aviation lighting is used, for example, either to provide a signal light visible to the eye (beacons, signals, runway marker or taxi lights etc.); or, less frequently, to render objects visible (aircraft landing lights, floodlights). The range at which the light or target will be visible just conspicuously enough for the purpose of safe navigation is usually the criterion of performance; and the ranges are nearly always long. The limiting conditions, in which the equipment can function, are usually determined by the transmission of the atmosphere.

It is characteristic of the eye that it is not possible to determine with great precision the conditions in which a given light is just not conspicuous enough, or at which the ground (for example) is just not sufficiently clearly revealed. In any case, the range at which it is required to see a light cannot even be specified precisely, and is often arrived at by estimates which in the nature of things cannot be exact. In the weather conditions in which the limit of safety of the lighting system is being approached, the range is determined mainly by atmospheric conditions; and may vary rapidly with changes in the atmosphere which are themselves considerable, indeterminate and out of control. In such circumstances changes in light intensity have a comparatively small effect on the limiting range. In clear weather, when the light intensity has a greater effect upon the limiting range, the latter is often arrived at by estimates in which interest.

For example, consider a night when the meteorological visibility range is 1,000 yards and a light is required to be visible at 2,000 yards. If the threshold eye illumination of 0.5 mile-candle is assumed for design purposes, the necessary intensity for white light at night is 1,300 candles.[1] But if the range required is increased by 10 per cent to 2,200 yards the intensity required is 3,000 candles, which is more than double the former value. If the visibility improves a little to give meteorological visibility range of 1,200 yards instead of 1,000, the necessary intensity becomes 350 candles. These figures are based upon a value often assumed for design purposes for the practical limit of signal lights, *viz.* 0.5 mile-candle. But various authorities have estimated the practical limit between 0.26 and 0.78 mile-candle, which for a required range of 2,000 yards and visibility range of 1,000 yards would make the necessary intensity between 675 and 2,030 candles. Military applications in which a light must certainly not be seen at some given range might involve the extrafoveal threshold which is variously estimated from 0.002 to 0.029 mile-candle, and which might be interpreted as meaning that a light of 5.2 candles might just be seen occasionally in the above conditions. When the projector is intended to make non-luminous objects visible at a distance, the required intensity is still more variable because (among other factors) the range through the atmosphere is increased and because the varying properties of the target are involved.

It is also necessary to estimate the precision to which an intensity needs to be determined by experiment in view of the precision with which it will be reproduced in practice. The intensity from a narrow beam projector in a given direction will depend markedly upon the position of the lamp in the optical system, and upon the setting of the optical system in the projector, as well as on the training of the projector as a whole. When a number of projectors is in question, as for a system of approach and contact lights, it is necessary further to consider the variation from one projector to another of both the optical systems and the lamps, and their settings, in combination, as well as the tolerances to be expected in training individual projectors. The whole problem, if considered formally, would involve a considerable statistical analysis, upon the data for a given piece of equipment, which is seldom available in the required form; for the moment it is sufficient to observe that there is little point in using refined procedure to determine the luminous intensity of a projector correctly to 5 per cent, if the changing of a lamp or reflector for a spare is likely to change the intensity by 20 or 30 per cent and when a change of 2:1 can occur before the working range is significantly altered.

*Publication authorized by the British Illuminating Engineering Society;[2] approved by the Council of the American Illuminating Engineering Society, March 1952.

**Committee members: F. C. Breckenridge, *Chairman*, J. A. Bartelt, H. R. Blackwell, G. M. Kevern, W. E. K. Middleton, H. J. C. Pearson, L. C. Simpson, R. T. Tousey, M. A. Warskow, R. C. Blatt.
Board of Editors: F. C. Breckenridge, H. R. Blackwell, C. L. Crouch, W. E. K. Middleton, J. M. Waldram.
Author: Past President and Fellow, British Illuminating Engineering Society; Fellow, British Institute of Physics; Research Laboratories of the General Electric Co., Ltd., Wembley, England. T. H. Projector of the National Bureau of Standards, Washington, D. C. collaborated by furnishing material relating to United States practices.

Notwithstanding these arguments, it is important to take the usual photometric precautions, to use accepted technique and to avoid systematic errors. The special difficulties attendant upon long range photometry are often sufficient to reduce the accuracy to ±15-20 per cent,* even when all reasonable precautions have been taken; and if they are not taken, the measurements may go out of control. Nevertheless, the problem of the photometry of projectors lies as much in the study of the projector itself, its optics and its proper adjustment, as in the measurement of its intensity; and the interpretation of the results is not always straightforward.

6.1.1—*The Meaning of Luminous Intensity*—The purpose of most projectors reduces in practice to the provision of illumination at a distance, whether the projector is intended specifically for this purpose or for the production of a signal light. Even when there is no real surface to illuminate and the light is to be looked at directly, it is nevertheless the illumination on a fictitious surface at the observer's eyes which determines whether or not he will see the light.

If a series of measurements of illumination is made at increasing distances from a light source, it is found that (in the absence of atmospheric scatter or absorption), the illumination is related to the distance by the law of inverse squares, to a degree of approximation which improves as the distance increases. If then the illumination is measured at some known distance at which this law applies sufficiently closely, then the illumination at any still greater distance can be found by calculation. It is then convenient to determine the luminous intensity, as a useful simplification. But the quantity known as luminous intensity is useful only as a step in a calculation which is valid only in certain defined conditions; and if those conditions do not apply, "luminous intensity" has no meaning, and the calculation is invalid. Projection equipment is occasionally used at distances at which the inverse square law does not apply; in such circumstances it cannot be said to possess "luminous intensity," and performance must be measured by direct illumination measurements at the working range. It is thus important to know, in any given case, the least distance at which it is justifiable to assume the inverse square law; and the least distance at which photometric measurements can be made from which performance can be estimated at greater distances with an accuracy *sufficient for the purpose in hand*. This latter phrase is important, for if a reasonably large tolerance is permissible in the determination of luminous intensity, it may be possible to take certain photometric liberties—provided their effects can be estimated—and greatly simplify the experiment, without prejudicing the final result in terms of operational range in some stated conditions.

6.1.2—*Limitations of the Inverse Square Law: Ideal Optical Systems*—To determine the limitations of the inverse square law it is convenient to consider a point at the receptor which receives light from a projector or light source of finite subtense.

(1) Consider first a light source in which every point of the source has the same brightness in all directions, such as a large opal sphere with a lamp in it. If the receptor approaches the light source, departures from the inverse square law will occur because the angle of incidence on the receptor of the light from the margins of the source reduces, by operation of the cosine law, the illumination which it produces. A significant error occurs, for a disc source, only when the receptor is quite close to the source; the error is 5 per cent when the receptor is distant 4½ times the diameter of the source.[7]

(2) A variant of this case occurs when the brightness of the source is not uniform from point to point of the source, but when at any one point the brightness is the same at all relevant directions of view; an example would be an opal globe not uniformly bright, or a bare lamp. The distance at which a given error occurs may be of the same order as in the first case; its value depends upon the kind and degree of non-uniformity of brightness over the source.

(3) A more complex case, which is is usual with projectors, occurs when the brightness at any point of the projector aperture, as seen from directions near that of the receptor, varies markedly with direction of view. If then the receptor is too near the projector, the brightness of some parts of the latter may differ from their value for a receptor at a great distance, because those parts are viewed from a slightly different direction, and the determination of the least permissible photometric distance involves a study of the projector itself in some detail.

For this purpose it is convenient to trace rays back from a point at the receptor through various parts of the projector. After reflection or refraction of the optical system some such rays will arrive at a bright part of the light source; the corresponding parts of the aperture of the projector will therefore appear bright. With a perfect optical system (designed to give light parallel to the axis) and a finite and uniformly bright source at the focus, for points near the axis at a great distance the whole of the projector aperture will appear bright; the projector is then said to exhibit "complete flash" and its luminous intensity is maximum (for the brightness of the source used). If the brightness of the source is uniform, if the receptor approaches the projector the flash will still appear to be complete so long as all rays traced from the receptor to the margin of the mirror pass after reflection or refraction through some part of the source, and the correct luminous intensity will be measured (unless of course the source is very large, so that the distance can be reduced to the point at which the angle of incidence of light from the margins is excessive, as in the first case discussed). Beyond that point, the rays from some part of the projector aperture will fail to reach the source and the flash will be incomplete; the intensity measured will be low. For a perfect optical system and an idealized light source, such as a disc, line or sphere, centered upon its focus, it is possible to calculate the "crossover point," *i.e.*, the point at which the marginal rays of greatest deviation reach the axis; this is the least distance at which the full-flash luminous intensity can be measured for a source centered upon the focus. Formulae are given by various authorities[1, 2, 6, 11, 19] (see Appendix).

*Rey and Favrot[20] estimate, for axial measurements on carbon arc searchlights under very good conditions, a probable error of 10%. Winch[6] quotes a similar accuracy. These accuracies are obtained only with great care.

For directions of view well off the axis it is inevitable that only a partial flash will occur and the case becomes more complex. It is again possible to compute (for a perfect optic and idealised source) the least distance of measurement at which no theoretical error occurs, which is usually greater than for the axial case. In some cases the distance becomes infinite — a result which demonstrates that such estimates are rather academic. Walsh[2] has shown that the error resulting from a reasonable transgression of the theoretical limit is negligible (see below).

6.1.3 — *Limitations of the Inverse Square Law: Practical Optical Systems* — These theoretical conclusions have to be modified in practical cases. Optics are never perfect, and often have least circles of confusion comparable in size with that of the source employed; sources are in practice far removed from the ideal sphere or disc assumed in the calculation and are very seldom of uniform brightness. As a result, a ray traced back through a point on the projector aperture does not arrive at a determinate point on a uniform disc or sphere source, but may arrive anywhere over the surface of a source the brightness of which is very variable, and may miss it entirely. Even for a receptor beyond the theoretical "crossover point" for a perfect optic, therefore, the flash may be incomplete, or although apparently complete, various parts may have different brightnesses as a result of the errors in the optic and the variations in brightness over the source. In practice, therefore, the calculation of the "crossover point" may have a restricted significance.

There is also the problem of the adjustment of the projector. Unless the focus is fixed, it becomes necessary to adjust the source relatively to the optic and to train the whole projector in order to find the maximum intensity and to explore the light distribution of the beam. The focusing must be carried out on the photometric range at a distance less than infinity, and with imperfect mirrors and non-uniform sources it is practicable only to adjust the projector for the range used. The question of what would have happened had the projector been adjusted for best focus at infinity may in many cases also become academic.

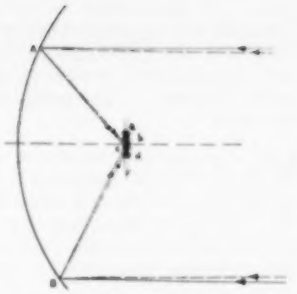


Figure 1. Effect of focusing for testing range.

It will be seen, however, that if the projector is adjusted to give the optimum result at the distance at which it is being tested (provided that the optical system permits and validates such adjustment) the conditions become very nearly the same as those for a receptor at infinity and a source centered upon the focus, even if the source is non-uniform and the optical system has appreciable errors of figure. If this can be done, it is possible to measure with adequate accuracy at distances well within the "crossover point," though it is difficult to lay down precise rules for the safe photometric distance for a given error, for the extent to which liberties can be taken depends upon the projector and the required accuracy.

For example, in Fig. 1, consider a parabolic mirror of imperfect figure, having a large filament lamp with the filament centered closely about the focus. The filament has four coils at a, b, c, and d. Suppose that the position of the filament shown gives the highest intensity for a receptor at infinity. Rays traced back from such a receptor through two points A and B on the mirror are shown by solid lines; owing to slight imperfection in figure, the ray reflected at A crosses the axis just behind the focus, and that reflected at B crosses just in front of it, and they both strike coil c of the filament. From a very distant receptor therefore, A and B are both flashed by coil c. If the receptor is advanced closer to the projector, rays from the receptor to A and B are now no longer parallel to the axis and might follow the path shown by the dotted lines. After reflection they cross the axis further from the pole of the mirror, and both go through gaps in the filament structure, that from A going between limbs b and c, and that from B between c and d. From the nearer receptor, therefore, points A and B will no longer be flashed; the flash pattern will have changed. But if that lamp is moved out through the small distance shown by the dotted line, it will be seen that the original condition is restored, and the rays after reflection strike the same limb of the filament in the same point.

Winch and his collaborators[21] investigated a 156 cm searchlight and a 150-ampere high-current density arc, the central portion of the arc, which was of approximately uniform brightness, having a diameter of about 3 mm. The theoretical "crossover point" for non-axial measurements was then calculated to be about 4,000 feet for a 3 mm disc source and about half that distance for a spherical source, the arc being somewhere between the two. Careful measurements were made of the cross section of light distribution at 1,500 feet and 5,000 feet, the projector being focused to give the optimum flash for each distance in turn. It was found that *provided that the projector was so focused* the results either on or off the axis for the two distances were indistinguishable within the errors of measurement. This was confirmed theoretically for sources as small as 2 mm in a 156 cm diameter 65 cm focus paraboloid. This means that for the shorter range the light source was not centered on the true focus of the mirror; but the displacement was of the order of 2 mm only, which was of no consequence. Had the arc been set by the focuscope to the measured focus of the mirror, a perceptible error would have occurred. While it is difficult to dogmatize, it might be taken as a guide that provided that the projector is focused for maximum intensity and optimum flash at the receptor, and provided that the change in lamp position which this entails does not result in a significant change in beam divergence, the intensities found will not differ significantly from those found at greater ranges.

6.1.4—*Selection of Length of Testing Range*—It is important to use as short a range as possible for the difficulties of measurement increase rapidly with increase in range and the theoretical advantages on the longer range may

easily be counterbalanced by the greater uncertainty of measurement there. Since it has been shown to be possible to photometer accurately projectors as large as 150 and 200 cm are searchlights at 1,500 feet and since such ranges do not present serious difficulties in photometry, it should be unnecessary to use longer ranges for any projectors likely to be used in aviation problems; smaller projectors can be measured safely at smaller ranges. Thus, even very critical projectors may be safely photometered at 700 times their focal length and probably less; and smaller and less critical projectors at say 30 to 50 times, provided that they are focused for optimum flash at the range used. With some projectors, however, it may be impracticable to adjust the focusing of the lamp for the distance of measurement, for example, with optics of the lighthouse type in which the optical system rotates about a central lamp; and where moreover both dioptric and catadioptric elements are used, one of which requires that to correct for the testing range, the lamp should be moved away from the optic end and the other that it should be moved towards it. In such cases, the theoretical "crossover point" may form a guide to the least safe distance of photometry. It is also necessary to allow for chromatic aberrations when testing dioptric projectors of critical performance.[8, 11]

6.2 — *Problems of Photometry of Projectors over Long Ranges* — The determination of the luminous intensity of a projector over a long range necessitates (1) the adjustment of the projector to the desired performance; (2) the training of the projector into known directions relative to the receptor; and (3) the determination of the luminous intensity, either from the illumination received at a known distance, or by comparison with that of a known projector. It is usual to determine the luminous intensity as in perfectly transparent air, so that allowance for atmospheric transmission can be made when the data are used; this may involve in addition the determination of the atmospheric transmission over the photometric range when the luminous intensity is measured. Methods for carrying out these operations will be described, mainly with reference to long testing ranges; simplifications possible at shorter ranges will be obvious. It is not proposed to discuss techniques and apparatus which are common to any photometric experiment; what follows is confined to the special problems of photometry of projectors.

6.2.1 — *Focusing and Adjustment of Projectors* — In most projectors it is possible to adjust the light source in position relatively to the optical system, and before commencing photometry it is necessary to adjust the projector.

Many projectors used in aviation will be designed for maximum concentration of light and complete flash, relying on the size of the light source and possibly a spread lens to produce the required divergence of the beam. If a spread lens is used, it can be removed and the projector set to maximum intensity. In some cases the projector is provided with sights whereby the lamp can be set at the focus of the optical system, which should be correct if the projector is to be set for infinity. It is, however, always desirable to check that such sights have themselves been properly set and that the projector is giving its optimum performance; and in any case it is desirable for the reasons discussed in 6.1.3 above to adjust for the optimum performance for the test range rather than for infinity. This can be checked for complete-flash projectors by adjusting either for optimum flash, or for maximum intensity; in practice, both criteria may be used in cooperation. A study of the flash is most useful for preliminary adjustment and to reveal the causes of departures from expected performance, and is a good guide to what is happening during adjustment; for the final stages, a more sensitive indication is often obtained by setting to the maximum luminous intensity. For the study of the flash, a flash camera, described in 6.3.2 below, is invaluable; it should enable a large image of the aperture of the projector to be studied at the receptor, and may enable photographs of the flash to be made for record and study.

Projectors which are not complete-flash, but which are designed with a partial-flash reflecting or refracting scheme to give a desired distribution, cannot be so simply adjusted; but if the intention of the design is known it is possible to study it with the aid of the flash camera and to check whether it is performing properly.

The use of a flash camera in conjunction with a special artificial source also enables a study of errors of optical systems to be completely explored,[21] but this investigation goes beyond the photometry of projected light.

A method for focusing and alignment of carbon arc searchlights which sets the projector for the photometric distance, and may be practicable where other methods are not, is used in some laboratories.[22] A hollow sighting tube with pinholes at both ends is substituted for the positive carbon. The searchlight is then aligned so that the tube is directed at the photometer. Then a small white card is pasted to the end of the tube at the location of the positive crater. If the reflector is in approximate focus and alignment, an image of the photometer will be visible on the card. If this image is centered on the card, symmetrically distorted, and brought into optimum focus, the searchlight is both aligned and focused for the photometric range.

The optical axis of an optic such as a good parnboloidal mirror can be determined by stretching two elastic cords across the front aperture so that each bisects the other, using their intersection and the image of their intersection to determine the axis; the lamp can be set upon this axis. The assumes that the mirror axis coincides with the mechanical axis. Many mirrors have the position of their pole marked on the mirror itself; the lamp can then be set so that the filament, the pole mark and the image of the filament are colinear.[22]

To determine the amount of obstruction due to lampholders, focuscopes, ventilating ducts, etc., a small tungsten filament lamp may be placed at the focus and a sheet of translucent paper placed over the front aperture. The shadows of obstructions then appear on the paper and can be traced in pencil.[19]

6.2.2 — *Training of Projector* — It is necessary to train the projector through small known angles in both elevation and azimuth so that the light distribution can be fully explored over the whole beam. When the beam is narrow this involves taking observations at intervals of, say, 0.1 degrees, and for projectors without suitable

mountings it is necessary to provide an accurate and rigid turntable, with the necessary slow-motions and scales. Some designs of turntables are described in 6.3.1 below. For very large projectors, or projectors which cannot conveniently be rotated, the receptor may be moved about the projector;[27] this may be convenient for field tests but is a cumbrous undertaking for a permanent range. Angles are obtained very accurately, but weathering and change of temperature introduce difficulties. In field tests, particularly upon projectors with fan beams such as airport floodlights, it is important to survey the site for change in level and to correct accordingly.[11]

TABLE I.—Measured Illumination Method.

Advantages	Disadvantages
Avoids use of standard projector, and its calibration, power supply, etc. More flexible for field work.	Not a substitution method. Atmospheric transmission must be separately determined; this requires telephotometer and light source, or equivalent, as well as illuminometer; usually possible only at night.
Calibration procedure simpler.	Length of range must be accurately known.
	Photometric scale resides in illuminometer.
	Cannot frequently refer to standard.

TABLE II.—Standard Projector Method.

Advantages	Disadvantages
Independent of atmospheric transmission and length of range.	Need for standard projector and supply. (Need to calibrate and check standard projector, if standard lamp cannot be used.)
Absolute calibration resides in standard projector, or lamp, frequent reference to standard possible.	Less suited for field work.
Quicker than illumination method.	
Can be used in daylight, with adequate shielding.	

6.2.3—*Procedure in Determining Luminous Intensity*—The luminous intensity can be determined in one of two ways; either as the absolute illumination received at a known distance, corrected for atmospheric transmission, or from the ratio of the illumination received from the test projector to that received from a standard projector the intensity of which is known.

The first method has advantages for field tests, and may be called for when no standard projector is available. Its advantages and disadvantages are set out in Table I.

The second and preferred method, using a standard projector, is a pure substitution method with its usual advantages; the atmospheric transmission is automatically allowed for, and the length of the range does not enter. There is, however, the difficulty of calibrating and checking the standard projector, which may be quite troublesome, though with sensitive equipment it is possible to refer the calibration back to a standard lamp which can be calibrated on a bench in the photometric laboratory. This method is better suited to established ranges than to field tests. The advantages and disadvantages are set out in Table II.

It is assumed that usual photometric procedure will be followed for maintaining constant voltage upon lamps, using lamps of known light output and correcting the results to the published light output at rated volts, etc. If lamps are underrun to ensure stable light output, they should not be underrun so far as to disturb the normal brightness distribution of the filament; this might occur with heavy-current low voltage lamps in which the filament is short and in which there is considerable end cooling. Underruning by 10 per cent in voltage is usually sufficient and safe. It is necessary to check zero readings, stray light, etc. and to make the necessary corrections, and it is wise to refer frequently to the standard projector. The program of observations should be such that errors due to variation in transmission, stray light or sensitivity will be detected and eliminated as far as possible. Measurements should not be made when either the transmission is very variable or the daylight is rapidly changing (unless the stray light correction is negligible) or when "heat shimmer" is excessive. If the projector being measured subtends a small angle at the receptor, as is almost always the case, changes in refractive index of the atmosphere may cause fluctuations in the illumination of the receptor; and if the response of the receptor is rapid the readings will be unsteady and false peaks and depressions may be introduced into the measured distribution curve.

6.2.4—*Determination of Atmospheric Transmission*—Over ranges exceeding a few hundred feet it is necessary to make allowance for atmospheric attenuation, or to exclude its effect by the procedure used. The latter scheme is the more satisfactory; the pure substitution method, using a standard projector achieves this result. If this is impracticable, the transmission must be determined over the full testing range. Even with the pure substitution method, trouble may occur from variations in atmospheric transmission during the experiment which may be sufficiently rapid to upset the results.

The transmission varies exponentially with the range used, and its determination is a major problem at long ranges; as the range increases not only does the transmission fall rapidly but it becomes much more unsteady. Mainly for this reason it is desirable to keep the testing range as short as possible. The chart of Fig. 2[16] is useful as an indication of the manner in which transmission changes with range, and also of the transmission to be expected in various conditions of daylight visibility. The curved lines relate transmission to range for a given scattering coefficient, the value of the coefficient being marked against the lines. The corresponding descriptions as used in the meteorological service are also appended. The meteorological visibility range is given by the intersection of one of the curves with the line marked "daylight visibility range line," for the transmission of the atmosphere at the daylight visual range can be taken at about 2 per cent. The transmission for any shorter range can be read from the chart by following up the corresponding curved line until it intersects the vertical line corresponding to the range concerned. For example, on a day of "moderate visibility" when a daylight visual range is 20,000 feet (approximately 4 miles) the transmission over a testing range of 1,000 feet would be about 81 per cent; on a 100-foot range it would be almost 100 per cent, and on a 5,000-foot range about 37 per cent. (These figures would not be reliable for corrections in an experiment, for they

assume an uniform atmosphere. They are given for illustration.)

The difficulties of measuring atmospheric transmission also vary with the range. At short ranges and in clear weather the transmission is high, and needs to be determined accurately only if it is desired to extrapolate to find the transmission at a greater range — a procedure which is not to be recommended. When measured over the testing range, the necessary accuracy of measurement corresponds to that of the photometric accuracy required; but at long ranges the optical magnification is often inconvenient.

Two general methods are available: the measurement of the apparent intensity of a light source of known and fixed intensity, and the measurement of the apparent brightness of an illuminated screen of known brightness. The former method has two variants: the use of visual photometers of the stellar or Maxwellian view type, viewing the light source directly, or the measurement of the illumination from the source, using a receptor similar in principle to that used for the photometry of the projector. The apparatus involved will be discussed under 6.3.5 below. In this scheme it is necessary to know the range accurately. The second method is simpler in operation and the photometry is easier when visual photometry is used. The brightness of the illuminated surface at the distant station must be accurately known, but the range does not enter in the determination of transmission.

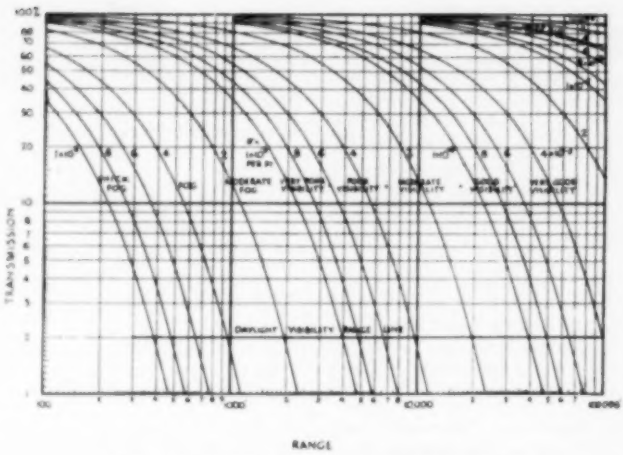


Figure 2. Transmission, range and scattering coefficient.

A portable visual photometer can be used to determine the distant screen brightness and also to determine the brightness of a local screen by which the telephotometer can be calibrated. At long ranges, however, the dimensions of the screen and of the optical system become inconveniently large, and the determination by this method becomes a formidable undertaking.

Other methods have been used; Hampton[11] determines the apparent intensity of the test projector at a number of distances; the logarithm of the apparent intensity plotted against distance should give a straight line which, when extrapolated to zero distance, gives the true intensity without atmospheric effects. Harcombe[3, 4] employs a two-station method with receptors at different distances; from measurements at the two distances the atmospheric transmission can be eliminated. These methods have disadvantages; they involve making some measurements at distances greater than necessary; they take longer; they assume a uniform atmosphere, which cannot be relied upon; and they require that the training of the projector should be precisely the same for each station. With some light distributions the training is not critical but with narrow distributions it is difficult to ensure that the intensity presented to each receptor is in fact the same.

Other methods of estimating the atmospheric transmission include observation of the daylight visual range, mentioned above, and nephelometric methods.[16] Except where they indicate that correction for atmospheric transmission can be neglected they are to be avoided, for they are less accurate and do not measure the transmission over the testing range.

Figure 3a. Turntable and goniometer based upon searchlight mounting.

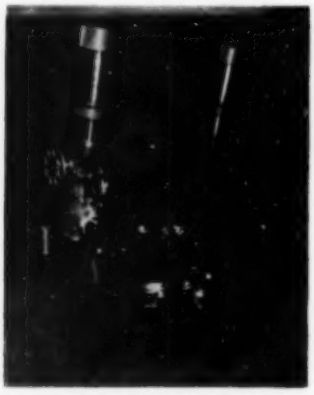


Figure 3b. Turntable and goniometer based upon dividing tables.

6.3—*Special Apparatus Required for Photometry over Long Ranges*

6.3.1 — *Turntable and Goniometer* — Most laboratories design turntables appropriate to their own work; a searchlight mounting often forms the

basis (Fig. 3A).[1, 15, 25, 26] The usual requirement is a flat rigid table to which the apparatus can be attached, which is capable of rotation in azimuth and of tilting in elevation; for many purposes restricted angular ranges are sufficient. The movements must be accurate and rigid, and the table suitable for heavy projectors. In some turntables the platform is adjustable in height.[25] A slow-motion mechanism is very desirable, which can be disconnected for convenience in setting-up.

T. H. Projector describes (private communication) a goniometer,[32] having an additional axis of rotation so that measurements can be based upon either a vertical or a horizontal polar axis (Fig. 3B).[2] This goniometer is constructed so that two of the rotations are obtained with rotary dividing tables of the type used in machine shops. A constant torque device, visible in the figure, ensures the taking up of backlash after the inner frame is balanced with the adjustable counterweights.

For making a temporary turntable to take a heavy projector the horizontal bearing has been formed by a spider carrying three ball-bearing wheels set at the extremities of three arms at 120 degrees. These wheels run on metal plates laid on the floor, and the base of the turntable structure rests upon them with similar bearing plates. A restricted vertical movement was obtained with an automobile jack. This arrangement will carry a large load, runs very easily, and requires no centering bearing; it can be moved by a tangent push-screw.[31] (Fig. 4)

Angular readings can be taken upon fixed circles, with verniers; or from the slow-motion gearing, if this is sufficiently accurate and free from backlash. Readings may often have to be taken at intervals of 0.1 degree, which indicates the precision and rigidity required in the turntable and index. One turntable[26] has an index with two pointers geared like the hands of a clock for convenience in fine reading. For narrow-angle projectors a convenient arrangement is a telescope mounted on the turntable or on the projector itself, observing a grid showing angles in bearing and elevation,[28] or, for smaller apparatus, a small projector imaging an index mark upon such a grid.[25] For very narrow angle work, the telescope may carry a reticle graduated suitably, and the image of the receptor is read against the reticle.[31] These methods avoid the need for accurate circles and centers, are conveniently set to zero, and may be applied to projectors such as searchlights having their own trunnions.

Where automatic recording is used, the motion of the turntable is transmitted electrically to the recorder, either a step-by-step motor,[29] by a periodic contact made by a commutator on the slow motion shaft,[32] or by the use of two synchronous motors connected to the same power supply. Fig. 3[1] shows a motor drive for automatic traversing, at uniform speeds, and the commutator for transmission of signals to the recorder.[32]

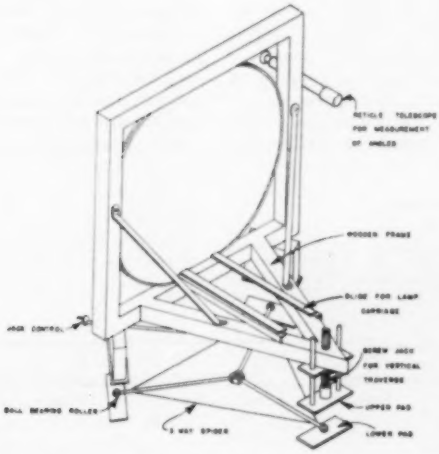


Figure 4. Temporary turntable for optical system of large projector. (For clarity frame is shown raised from spider and lower pads.)

6.3.2—*Flash Camera*—The flash camera should be capable of forming an image about 2-3-inch diameter of the projector aperture with reasonably good definition. At most long ranges a simple lens will have to be of inconveniently long focus; a camera in the form of a projecting telescope, having a projection eyepiece, is a convenient form.[10] It is also convenient if dark slides can be inserted in place of the ground glass focusing screen for taking photographs, and a shutter is also required. One design has used an objective of 3-inch diameter and 50-inch focus, with a projection eyepiece, on a range of 1,500 feet. Winch and his collaborators describe[21] more elaborate forms with objectives of 5-inch diameter and 47-inch focus, a reflex arrangement being used whereby the image can be observed up to the moment of exposing the negative. This is a convenience when fluctuating light sources are used. In another apparatus the flash camera is combined with the receptor unit, and the image could be observed with an eyepiece or photographed, as desired. (Fig. 5)

An ordinary telescope, with suitable dark glass, may of course be used[19] but is less convenient than the projecting telescope.

6.3.3—*Receptor Unit*—The receptor unit can take many forms. The essential is a test plate or photocell, shielded from all light except that from the projector under test. Visual photometry can be used but it is inconvenient and slow; for setting up and watching the effects of change of atmospheric transmission and for rapid work, a photoelectric apparatus is much to be preferred. When fluctuations occur either in the light source or in the atmosphere, rapidity in measurement makes for accuracy; for this reason, as well as for convenience in recording the detailed

variation of intensity with angle, continuous recording has advantages, and is strongly favored by some establishments.[29, 32]

Automatic recording can be made with a suitable oscillograph or recording galvanometer, preferably high-speed. In one establishment[32] a multi-element string oscillograph is used with galvanometers having sensitivities as high as 0.1 microamperes per mm and suitable for direct connection to a photovoltaic cell. Photometric and electrical measurements and training of the projector are simultaneously recorded, the latter by contacts actuated by the slow motion gear. This enables a curve to be obtained in 2 or 3 seconds. Automatic recording potentiometers can also be used; the high-speed types enable rapid photometry to be carried out. These elaborations though convenient are not essential for most work; a straightforward galvanometer with lamp and scale is very handy and adequate for medium ranges.

6.3.3.1—*Shielding* — It is a great convenience to be able to make measurements by day, but it is difficult to shield the receptor so that it accepts light from the test projector and is shielded adequately from stray daylight. The test projector should be placed in a fairly large building of dark color which will form a good back screen; preferably it should be placed within a dark room projecting its beam through an aperture say 6-10 feet square, the aperture not being close to the skyline as seen from the receptor. If possible, the use of a range running east and west should be avoided, otherwise low sunlight may be troublesome. The line of sight should preferably be well clear of the ground, to reduce light reflected from the ground (at night) and to avoid the layer of atmosphere close to the ground, which is most likely to be unsteady. Irregular terrain, and surfaces such as paved roads likely to be strongly heated by day, should be avoided. Conventional photometric shielding may be used, the first series of shields being fitted within a long black tunnel say 8-10 inches in diameter. Further large black shields can be used external to the tunnel and of such size and position that the receptor can see only the backs of the

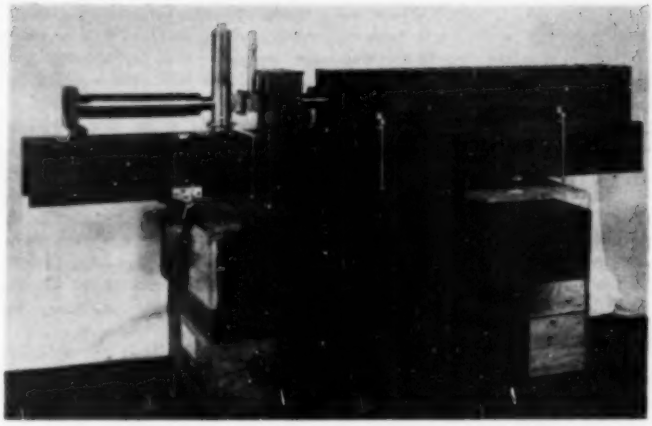


Figure 5. Combined tele-camera and photoelectric receptor.[31]

shields and the aperture through which the projector operates.[32] With photocells of usual dimensions the shielding becomes rather cumbersome, and there is also possibility of stray light reflected from the backs of the external shields, which are exposed to full daylight and possibly sunlight, and which, being exposed to weather, it is difficult to maintain really black. Such shields should preferably be hooded to reduce their illumination.

A more compact arrangement (Fig. 6) utilizes a form of telescope,[21] in which the objective lens forms an image of the distant projector upon a small pinhole just larger than the image of the projector placed at the principal focus of the lens. The only light passing through the pinhole is light received from the projector; all other light is focused elsewhere and is stopped by the diaphragm. After passing the pinhole the light diverges and reaches a photocell, after passing through a diffuser. Such an arrangement requires to be rigidly mounted and to have adequate slow-motions for adjustment and an eyepiece by which the image of the projector can be centered on the pinhole; it is also necessary to shield the surface of the lens from direct sunlight, since a little light is always scattered at the lens. Difficulty may be experienced in hot weather over long ranges from "heat shimmer" due to rising currents of hot air of varying density.

6.3.3.2—*Photocell and Filters* — The type of photocell used depends upon the sensitivity and the range required. For many purposes a photovoltaic cell is adequate and simple. The Weston Photronic cell has been used on several ranges.[28, 29, 32] It is important that any photoelectric cell should be used in conjunction with filters giving a good approximation to the standard

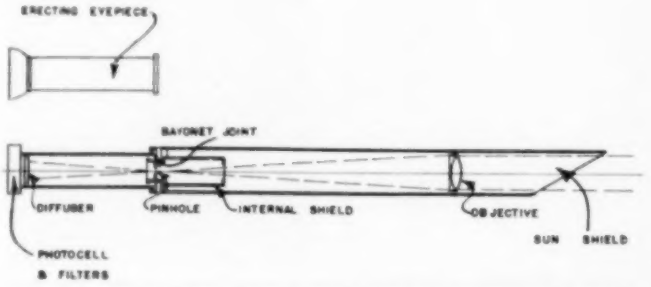


Figure 6. Optical shield receptor unit. (Simple type; diagrammatic only.)

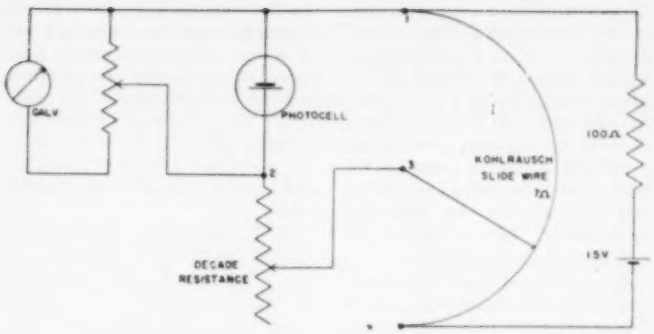


Figure 7. Circuit for photovoltaic cell.[14]

spectral luminosity curve, and that ultraviolet and infrared radiation should be excluded, particularly when the standard or calibrating source uses a light source different from that in the test projector. When mercury-vapor or carbon arcs are used this is specially important.

The circuit used with photovoltaic cells should be in accordance with usual photometric procedure. For most work a reflecting galvanometer is simple and straightforward and gives adequate accuracy, provided that the resistance in the cell circuit is chosen to give adequate linearity of response. An electrical attenuator of the universal shunt type is convenient, as it can be arranged to keep the resistance presented to the cell within the required limits and still preserve critical damping for the galvanometer. For more precise work, a circuit of the Campbell-Freeth type is often used, of effectively zero resistance, which gives a more nearly linear calibration (Fig. 7).[8, 12, 14] The linearity of the complete equipment of cell, attenuator and galvanometer should of course be checked. A commercial photoelectric illumination photometer may be used, with suitable filters; it should be checked for reliability, stability and linearity of response.[19]

Where greater sensitivity is desired, an electron-multiplier type of cell may be employed, using conventional circuits with accurately stabilized voltage supplies. This type of cell gives much greater sensitivity, but its stability needs to be watched.

Another type of instrument of high sensitivity and precise linearity uses a vacuum cell with an electronic-bridge amplifier; the cell and electrometer triode and leak resistance are hermetically sealed into a single unit.[8, 17] (Fig. 8) This apparatus in connection with the optical shielding unit described above is sufficiently sensitive to measure a 1000-watt lamp at 1,500 feet in daylight, though the correction for stray light is then a substantial fraction of the reading for the lamp. It is usually employed with a liquid filter of the Preston type giving a close approximation to the standard spectral luminosity curve.

It is possible to run a circuit from the receptor unit back to the projector, an arrangement which is very convenient since the measurements are all made at one end of the range; but it is necessary to guard against effects of capacity and of electrical leakage when very small currents are involved, particularly over long ranges.

6.3.3.3—*Optical Attenuators*—A receptor unit requires to be used over a very long range of intensities in order to step from the calibrating means to the peak intensity of a powerful projector. It is desirable to use strictly neutral attenuators such as sector discs, and discs with transmissions down to one per cent have been successfully used. At low transmissions, however, they require to be very well designed and made. In optically shielded receptors it is sometimes convenient to place the sector disc near to the principal focus of the lens; a small disc can then be used, which can be swung out of the way conveniently when not required. Another form of attentuator is a stop on the objective lens of the optical shield, which can be used provided that it does not unduly impair the definition of the image. Sector discs are inadmissable for a-c sources which exhibit periodic flicker, for which neutral filters provide convenient attenuators. They should be calibrated with light of the colors concerned and with the receptor and color filters used, particularly when the calibrating and test lights are of different spectral composition.

6.3.4—*Standard Projector*—The requirements for a standard projector are:—

(1) A maximum intensity capable of providing an adequate response at the receptor.
(2) A light distribution which is smooth and fairly broad so that the training of the projector is not critical.
(3) An optical system which permits of calibration at fairly short range, so that it can be calibrated in a laboratory without the need for a long range.
(4) A light source which is stable over long periods, and preferably unaffected by switching.

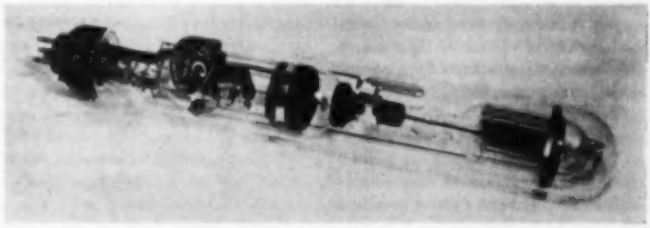


Figure 8. Photometer unit.[31]

Various forms of standard projector have been used: *e.g.*, a battery of sealed-beam headlights;[32] a lens spotlight;[30] a modified film studio mirror projector, with 5-kw tungsten filament lamp and diffuser;[31] and a searchlight mirror with a 0.5, 1.5 or 5-kw tungsten filament lamp and slightly diffusing front glass.[29, 30, 31] The tungsten lamps are always underrun suitably to ensure stability.

With heavy-current filament lamps there is some danger of change in calibration as the result of switching. For tests involving frequent reference to the standard, therefore, it is preferable to leave the standard projector switched on and to use a shutter to obstruct its light. It is necessary to check carefully at fairly frequent intervals the candlepower of the standard, and the accuracy of alignment of the sight by which it is trained on the receptor. In one laboratory[31] an auxiliary indoor range was provided, by which the intensity of the standard could be checked by a photometric bench at the other end. The standard projector could be trained from the calibrating to the test range without shifting its position.

If the receptor is sensitive enough, it may be possible to obtain sufficient response from a large bare tungsten filament lamp over the full range; the stray light in daylight is then rather large but can be measured and subtracted if steady. Such a lamp can be calibrated on the bench in the usual way, and it then becomes possible, by the use of suitable attenuators, to step from a bare lamp giving 1.5×10^3 candles to a standard projector giving 5×10^5 candles and thence to test projectors giving 10^9 or 10^{10} candles.[21]

6.3.5—*Apparatus for Determination of Atmospheric Transmission*—On permanent ranges when the substitution method is not employed, it is usual to employ a transmissometer in which the intensity of calibrated light source or projector is measured by a photoelectric receptor. Douglas[18] has described a photoelectric electronic instrument for permanent installation. At another testing range[29] a second receptor with continuous recording is used to receive light from a standard projector to record relative transmission continuously during a test. A simple instrument has been described by the Meteorological Office (Great Britain)[20] in which a small tungsten filament searchlight is used with a simple receptor having a photovoltaic cell and optical shielding. A small photocell on the front glass of the searchlight is used to monitor the light source; the indications of the cells are read on a taut suspension galvanometer. This is suitable for ranges up to about 1,000 feet.

Rey and Fevrot[19] describe a slightly different method, in which the total flux in the beam of a very narrow angle projector is measured. The projector consists of a very small tungsten filament lamp at the focus of a precise lens, 18 cm diameter, very accurately set and focused. The whole beam, which is only about 25 cm diameter at a range of 300 meters, is received on a mirror which is one quarter of a large searchlight mirror having its focus offset, and is focused upon a receptor consisting of a ground glass window with a photocell a few inches behind it. For calibration the whole receptor is transported to a position near the projector.

Any permanent transmissometer installation calls for rigid and precise mounting of the components, and great care to ensure the maintenance of the intensity of the standard projector presented to the receptor.

Collier[13] has described a number of visual telephotometers and discussed the principles involved in their design and use. For the measurement of the apparent intensity of a distant light, instruments of the Maxwellian view or stellar type have the advantage that they can be used with lamps of comparatively low power and do not require standard projectors; this avoids the difficulties of accurate mounting and maintenance of a projector. The calibration of these instruments may involve the provision of a second very small light source of known intensity close to the instrument.

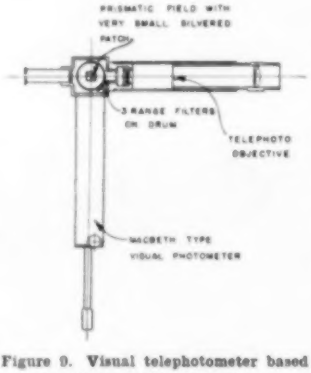

PRISMATIC FIELD WITH VERY SMALL SILVERED PATCH
3 RANGE FILTERS ON DRUM
TELEPHOTO OBJECTIVE
MACBETH TYPE VISUAL PHOTOMETER

Figure 9. Visual telephotometer based on Macbeth Illuminometer.

The second method, involving the measurement of the brightness of a distant illuminated screen, is simpler for visual photometry at medium ranges (say up to 1,000 feet) and for temporary work. The telephotometer can be sometimes adapted from an existing illuminometer and the distant illuminated screen is not necessarily inconveniently large. It may take the form of a telescope having a small prismatic field at its focus; with this form the angular field may be very small, which permits the use of a small target. Collier[13] has described several instruments of this form. A portable instrument has been used[16] having a one-inch diameter telephoto lens with an equivalent focal length of 21 inches attached to an instrument of the Macbeth type. (Fig. 9) A very small prismatic field was used. The target consisted of a 30-inch copper hemisphere painted white inside and illuminated by a small opal lamp at its center; this gives a very nearly uniform brightness and is easily portable. This arrangement works well at ranges up to 1,000 feet. Benford has described instruments intended to work over ranges of 2,300 feet and 3 miles, the smaller having an objective of 6-inch diameter and 18-foot focus and the latter an objective of 15-inch diameter and 30-foot focus.[1]

Telephotometers suitable for measurements over testing ranges are not commercially available and have generally been designed and made for particular ranges.

6.3.6—*Telephones*—Telephone communication between the projector operator and the observer at the distant station is essential; it has been found useful for one or both to be provided with headsets so that they can converse while making adjustment. Loud-speaking telephones of the inter-office type are also convenient on permanent installations.[32] Reliable equipment properly installed is necessary; range tele-

phones are proverbially exasperating, and can waste much time and temper on an important experiment.

6.4—*Photometry over Short Ranges* —The photometry of small projectors can be carried out over ranges of 100 feet or less, at which many of the problems discussed above vanish. The range can be indoors, which can eliminate the troubles due to stray daylight, and atmospheric problems are usually negligible—though in foggy weather, or in a dusty building, surprisingly large errors can occur. The photometric procedure then becomes much simpler. A turntable is still required, though there are many standard laboratory equipments which are suitable. Angles may be measured on less elaborate circles; the method using the telescope or projector is, however, often very handy, particularly when rather elaborate explorations are involved. It is particularly convenient to bring the leads from the photocell back to the projector, so that the experiment can be concentrated at one end of the range. This is safe with photovoltaic cells at short ranges of 50-100 feet. If it is inconvenient to rotate the projector, the beam may be formed on a screen and explored by a movable photocell or a visual photometer. If a flash camera is used, a mirror can be placed at the receptor so that the camera can be used alongside the projector—a great convenience in focusing and adjusting. A high quality plane mirror is required, of a diameter exceeding one half of that of the projector aperture. It is usually necessary to shield the cell from light reflected from walls, etc., but a simple shielding box is sufficient. The photoelectric equipment may be calibrated by reference to a visual illuminometer or other standardized instrument.

For the testing of floodlight projectors, the American I.E.S. specifies that the intensity shall be derived from measurements made at a distance of 100 feet, each determination being made with a receptor having an acceptance angle, measured at the projector, of one square degree. This is in order to avoid spurious high readings obtained from some chance striation which does not represent a useful intensity. The receptor can conveniently take the form of a square aperture in a shield, on the further side of which is an integrating hemisphere. A number of cells placed on the back of the shield receive light from the hemisphere.[25, 26]

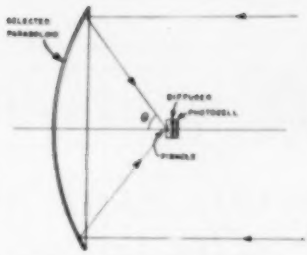


Figure 10. Optical photometric range. (NOTE:—This arrangement does not give correct quantitative results because light near the margins of the mirror traverses the pinhole obliquely and suffers a reduction of cos θ where θ is angle shown. But it will usefully indicate a maximum when focusing. To get a flash image exchange photocell for a neutral glass about 0.05 transmission (to act as light trap) and view diffuser directly).

Focusing is conveniently carried out by observing the pattern of the beam on a screen, though a check to ensure that the maximum peak intensity has been secured is advisable.

6.5—*Optical Photometric Ranges* —For approximate work, and for factory checking and setting it is sometimes possible to compress a long photometric range into a few feet, by the use of optical methods analogous to the optical shielding already described. For a receptor a large paraboloidal mirror of high quality is required, such as a selected searchlight mirror large enough to accept the whole of the beam tested. A pinhole stop is placed at its principal focus; the only light which can pass through the pinhole after reflection at the mirror is light which was incident on the mirror very nearly parallel to its axis. (Fig. 10) This light can be used to form a flash image of the projector projecting light on to the mirror, or it can be passed to a photocell to measure the intensity of the projector.[31] This method is valid only for approximate measurements and when the precision of the collector mirror is appreciably better than that of the optical system under test; but it is useful for a manufacturer's test of production equipment, and for setting up.

6.6—*Measurement of Beam Lumens* —The total flux in a beam of projected light may be obtained by integration of the intensity distribution, if this has been measured in sufficient detail. It is desirable that a complete isocandle distribution should be known, not merely the candlepower distribution in two principal planes at right angles.

A device similar to the optical photometric range has been employed to measure directly the total light flux in a projected beam[5] in which the projected beam is received on a collector mirror and is concentrated on to a water-cooled white surface. This surface forms a secondary source, from which the total light flux can be obtained. It is calibrated by reference to beams, the flux in which can be calculated from complete intensity measurements. A simpler method for determining the total flux in a beam is to allow the beam to impinge on a large white screen and to use the screen as a secondary source to illuminate a test plate or cell. The flux can be calculated if the reflection factor of the screen and its distance from the test-plate are known, and if it is a good diffuser.[16]

A more elaborate apparatus for the measurement of beam lumens was devised by Benford,[1] in the form of a large (110-inch) hemispherical integrator of sufficient aperture to receive the whole beam. The aperture of the integrator could if necessary be closed by a very large iris diaphragm, when measuring beams of small width. It was found that the integrator paint had characteristics which departed slightly from those of a perfect diffuser, and in order to compensate for errors which resulted, a series of masking fins was used which obstructed a small proportion of the light reaching the margin of the opening of the hemisphere.

Acknowledgments —The author is indebted to the organizations listed under references 24-32 for much information included in this communication, and in particular to F. C. Breckenridge, T. H. Projector and W. F. Little in the United States, and E. S. Calvert, J. G. Holmes, D. E. H. Jones, J. W. T. Walsh and G. T. Winch in Great Britain who have read the manuscript, and several of whom have made valuable contributions and comments.

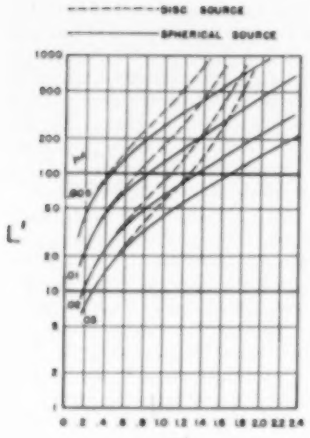


Figure 11. Crossover point for paraboloid mirror (on axis) (Hampton).

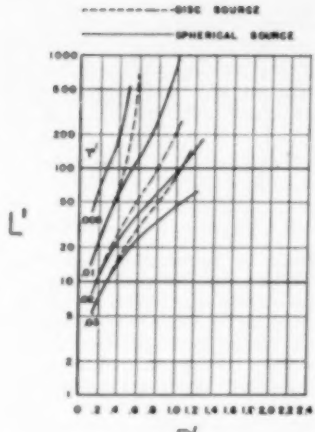


Figure 12. Crossover point for dioptric system (on axis) (Hampton).

Appendix

Distance of Crossover Point for Projection Equipment — The distance of the "crossover point" had been calculated by various investigators for equipment of various types, for sources idealized to either the sphere or the disc, and for axial or oblique directions. The distances are given by Hampton[11] for axial candles for parabolic mirrors and for dioptric lenses, and for either spherical or disc sources, by the following formulae, which are of the same forms as those derived by other workers; he has plotted the results in graphical form as given in Figs. 11 and 12.

Axial Intensity

1. Paraboloidal Mirrors
   (a) Spherical Source

$$L' = \frac{R'}{r'}(1 + \tfrac{1}{4}R'^2)$$

   (b) Disc Source

$$L' = \frac{R'}{r'}\frac{(1 + \tfrac{1}{4}R'^2)}{(1 - \tfrac{1}{4}R'^2)}$$

where R' = Radius of edge of mirror
r' = Radius of source
L' = Distance of crossover point from mirror edge

all expressed as multiples of focal length.

2. Dioptric Apparatus
   (a) Spherical Source

$$L' = \frac{\tan\theta}{r'\zeta\cos\theta - \eta\delta_{nR}}$$

   (b) Disc Source

$$L' = \frac{\tan\theta}{r'\zeta\cos^2\theta - \eta\delta_{nR}}$$

where R', L' and r' are as before:

θ is maximum angle to horizontal subtended by the extreme element

δ_{nR} is chromatic dispersion for red light measured from the wavelength for which the lens was designed ($= 0.004$ for Lighthouse Crown glass)

n is refractive index

$$\delta \text{ is } \frac{-\cos\theta\,(n^2 - \sqrt{n^2 - \sin^2\theta})}{n^2 - \sin^2\theta - \sqrt{n^2 - \sin^2\theta}}$$

$$\eta \text{ is } \frac{n\sin\theta}{n^2 - \sin^2\theta - \sqrt{n^2 - \sin^2\theta}}$$

For axial measurements, Walsh gives the approximate rule:—

$$L' = R'/r'$$

so long as the source of light is small.

Off-Axis Measurements

For points off the axis the theory is more complex, and is discussed in detail by Benford[1] and by Walsh[2] whose papers should be consulted for cases in which refined measurements are concerned. Hampton has discussed[6, 11] the theory of the dioptric lens.

For inclined directions, with a paraboloidal mirror Walsh gives the equation:

$$R/L = \frac{r(f - R^2/4f)}{(f - R^2/4f)^2} - \theta$$

where R, r and L are the above quantities in absolute units and f is the focal length and θ is the angle from the axis at which measurements are to be made.

References

1. Benford, F.: *G. E. Review*, Vol. 26, p. 75 (1923). Analysis and photometry of projectors.
2. Walsh, J. W. T.: *Optical Convention (London)*, Part I, p. 378 (1926). Analysis and photometry of projectors.
3. Walsh, J. W. T.: *Dictionary of Applied Physics*, Vol. IV, p. 461. Two-station method.
4. Harcombe, S.: *Optical Convention (London)*, Part I, p. 388 (1926). Two-station method; searchlight photometry.
5. Sylvester-Evans, C. H., and Gibson, H. C.: *Optical Convention (London)*, Part I, p. 407 (1926). Photometry of projector; flux measurement.
6. Hampton, W. M.: *Trans. Opt. Soc. (Lond.)*, Vol. 30, p. 185 (1928-9). Theory; dioptric lenses.
7. Walsh, J. W. T.: *Photometry*. Constable, London (1930).
8. Campbell, N. R., and Freeth, M. K.: *J. Sci. Insts.*, Vol. 11, p. 125 (1934). Circuit for photovoltaic cells.
9. Winch, G. T., and Machin, C. F.: *G.E.C. Journal (Lond.)*, Vol. 6, No. 4, p. 205 (1935). Photoelectric universal photometer.
10. Turner, H. J. A.: *Light and Lighting*, Vol. 30, p. 328 (1937). Flash camera.
11. Hampton, W. M.: *Trans. Illum. Eng. Soc. (Lond.)*, Vol. 3, p. 52 (1938). Photometry of projectors; flash; crossover points.
12. Atkinson, J. R., Campbell, N. R., Palmer, E. H., and Winch, G. T.: *Proc. Phys. Soc.*, Vol. 50, p. 934 (1938). Circuits for photovoltaic cells.
13. Collier, L. J.: *Trans. Illum. Soc. (Lond.)*, Vol. 3, p. 141 (1938). Telephotometry.
14. Barbrow, L.: *Nat. Bureau of Standards, J. of Research*, Vol. 25, p. 703 (1940). Circuits for photovoltaic cells.
15. Breckenridge, F. C., and Projector, T. H.: *U. S. Dept. of Commerce Civil Aviation Authority Tech. Rept. No. 39* (1944). Goniometer turntables.
16. Waldram, J. M.: *Trans. Illum. Eng. Soc. (Lond.)*, Vol. 10, p. 147 (1945). Properties of atmosphere; measurement of beam flux.
17. Winch, G. T.: *Trans. Illum. Eng. Soc. (Lond.)*, Vol. 11, p. 107 (1946). Photoelectric universal photometers.
18. Douglas, C. A.: *Electronics*, Vol. 20, p. 106 (August 1947). Photoelectric telephotometer.
19. Rey, A., and Fevrot, C.: *Revue d'Optique*, Vol. 27, No. 1, p. 35 (1948). Photometric range and telephotometer; accuracy.
20. Serase, F. J.: *J. Sci. Insts.*, Vol. 25, No. 6, p. 185 (1948). Telephotometer.
21. Cameron, H. K., Rayner, E. H., Thomas, E. R., and Winch, G. T.: *Symposium on Searchlights* (I.E.S. London, 1948). Photometry of projectors; receptors; flash cameras; procedure, etc.
22. Chivers, E. W., and Jones, D. E. H.: *Symposium on Searchlights* (I.E.S. London, 1948). Automatic recording.
23. Waldram, J. M.: *Trans. Illum. Eng. Soc. (Lond.)*, Vol. 16, p. 187 (1951). Photometry of projected light.
24. National Physical Laboratory, Teddington, England.
25. General Electric Company, U. S. A.
26. Westinghouse Electric Corporation, Cleveland.
27. Engineer Research and Development Laboratories, U. S. Army, Fort Belvoir, Va.
28. H. M. S. Vernon, England.
29. Radar Research and Development Establishment, Malvern, England.
30. Chance Bros. and Company, Ltd., Birmingham, England.
31. Research Laboratories of the General Electric Company, Ltd., Wembley, England.
32. National Bureau of Standards, Washington, D. C.

Questions and Answers on light sources

The I.E.S. Committee on Light Sources, under the chairmanship of E. H. Raddin, has prepared this listing of answers to frequently-asked questions. Readers are invited by the Committee to submit similar questions of general interest on light sources, to be considered for publication from time to time. Questions may be sent in care of Society Headquarters.

Do slimline type fluorescent lamps have less flicker than preheat fluorescent lamps?

Assuming that both types of lamps are of good quality and are operating on approved ballasts, the slimline types generally will have more measurable flicker (cyclic maximum and minimum light output compared to the average light output) than the preheat types. Although the difference is measurable, it is not perceptible to the eye. With 60-cycle current, the flicker in fluorescent lamps cannot be detected by the eye except at the extreme ends of the lamp and then only when the observer uses averted vision. The normal shielding of most fixtures eliminates this factor from consideration. The slimline types, being instant-start, do not have the starting flicker (blinking) observed with preheat types when the starter is attempting to start the latter. See "Stroboscopic and Flicker Effects from Fluorescent Lamps" by A. A. Eastman and J. H. Campbell, ILLUMINATING ENGINEERING, January 1952.

Do hot cathode slimline and cold cathode fluorescent lamp installations differ in the magnitude of audible hum?

There is no fundamental reason why there should be any difference under similar operating conditions.

What is the rated life of the cold cathode lamp?

The rated life of the type HP cold cathode lamp is 25,000 hours, and the rated life of the type LP cold cathode lamp is 15,000 hours.

Why aren't fluorescent lamps rated in volts?

Fluorescent lamps are not rated with respect to voltage because the lamp voltage is controlled by the ballast. The ballast is rated for a specific line voltage.

Are mercury lamps made by the various manufacturers and having the same wattage rating, interchangeable on the same ballast?

Not necessarily. Lamps of different manufacture are electrically interchangeable if the same ballast identification appears in their ordering designation. For example, there are 400-watt lamps, with either glass or quartz inner arc tubes, made by various manufacturers, which are electrically interchangeable on the ballast designed as H1. This ballast identification is part of the lamp designation. On the other hand, 1000-watt lamps are available which operate at different currents and voltages and therefore are not interchangeable on the same ballast. The ballasts for these lamps have different designations, which are part of the lamp nomenclature, and it is necessary to operate the lamp on the ballast called for in the lamp nomenclature.

Why do fluorescent fixtures require ballasts?

Ballasts are required to provide sufficient voltage for lamp starting and to limit the current through the lamp fo the proper value. If a fluorescent lamp were started without a ballast or resistor, it would immediately destroy itself, as the characteristics of the lamp would cause it to draw more and more current until it quickly failed.

See pages 8-42 and 8-51 of *I.E.S. Lighting Handbook*, 2nd Ed.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

National Technical Conference Advance Program Completed

A preview of what is ahead for I.E.S. members and guests attending the Chicago Conference at the Edgewater Beach Hotel, September 8-12, is indicated by the advance program of events mailed recently to the entire membership. Advance registration, now being compiled at headquarters, hints at record attendance.

Eleven sessions of papers will highlight the technical program. Preprints of the papers will be available to members attending the Conference at a cost of $1.00 per set. Those wishing to prepare discussions of particular papers may secure advance copies, if available in time, by writing to: Illuminating Engineering Society, Publications Office, 1860 Broadway, New York 23, N. Y.

The Lighting Service Forum, always a stimulating affair, will this year carry the additional challenge of inter-Region competition. Winners of the Regional contests for "My Most Interesting Lighting Installation," will compete as finalists for the grand prize winner at the Lighting Service Forum.

Entertainment includes two parties. In addition to the President's Reception and Banquet on Thursday evening, a gala "Roaring Twenties" party is scheduled for Monday, September 8. Simple "Twenties" props are suggested for this affair. A special ladies' program is also planned, timed well with joint affairs.

The 100th Anniversary of engineering is also being celebrated in Chicago, September 8-12. The centennial celebrations, in honor of engineers in every branch of the profession will be held at the Museum of Science and Industry in Jackson Park. Exhibits and stage productions depicting the progress of engineering will be features of this celebration.

Papers Scheduled

The full papers program, with the preprint numbers assigned to them are listed as follows:

1. "Are We Confusing Eyes with Vision" by D. B. Harmon, Austin, Texas.
2. "Brightness Difference—A Basic Factor in Suprathreshold Seeing" by S. K. Guth, A. A. Eastman, R. C. Rodgers, General Electric Co.
3. "Silhouette Lighting of Small Diameter Wires" by Willard Allphin, Sylvania Electric Products Inc.
4. "Visual Detection Data for the Specification of Illumination Level" by H. R. Blackwell, University of Michigan.
5. "Low Pressure Mercury Discharge" by George Meister and T. H. Heine, Westinghouse Electric Corp.
6. "Factors Affecting Fluorescent Lamp Performance" by E. P. Lowry, Sylvania Electric Products Inc.
7. "A Study of Color Rendition by Fluorescent Lamps" by A. C. Barr, C. N. Clark, J. Hessler, General Electric Corp.
8. "The Attainment of Quality Daylighting in School Classrooms" by R. A. Boyd, University of Michigan.
9. "A Lumen Method of Daylighting Design" by R. L. Biesele, Jr., Southern Methodist University; W. J. Arner, Southern Methodist University; E. J. Conover, Southern Methodist University; Res. Dept. Libbey-Owens-Ford; Res. Dept. Detroit Steel Products Co.
10. "The Importance of Ground Reflection in Day-Lighting" by J. W. Griffith, Southern Methodist University; E. W. Conover, Detroit Steel Company; O. F. Wenzler, Libbey-Owens-Ford Glass Co.
11. "Controlling and Redirecting Daylight by Means of Louvers" by H. S. Ball, University of Michigan.
12. "A New Daylighting Survey Technique Utilizing a Photographic Recorder and Physical Brightness Meter" by H. F. Kingsbury, W. H. Billhartz, R. W. McKinley, Pittsburgh Corning Corporation.
13. "Reflectorized Mercury Lamps and Their Industrial Applications" by E. B. Noel, E. A. Linsday, General Electric Company.

To the members of the Illuminating Engineering Society

I AM INVITING YOU and as many of your organization as can possibly attend, to join with the other leaders in the lighting fraternity at the National Technical Conference of the Illuminating Engineering Society at Chicago this September 8-12.

The business sessions open Monday morning the 8th and in ten or more half-day conferences there will be authoritative papers by leaders of industry and science covering such topics as the Influence of Light on Life; the Types of Seeing; New Light Sources and Circuits; Better Use of Daylight; Doing New Things with Color; The Comfort and Costs of Industrial Lighting; Color Television; How to Make Streets Visible and Newest Things in Fluorescent Fixture and Ballast Design, plus latest methods of simplifying lighting calculations.

One highlight will be the evening presentation of the annual Progress Report. Then there will be the vivacious contests and awards for "My Most Interesting Lighting Job," and Friday morning's Residence Lighting Forum.

All this will be at the delightful Edgewater Beach Hotel, so plan now to arrange your business or vacation schedule to take advantage of this Conference. Nowhere else can you meet and discuss with so many industry leaders the key topics and problems of today and tomorrow. The ladies will also find this Conference delightfully worthwhile. Unique and special events are planned for them. Added value will be the sessions of the Centennial of Engineering in Chicago during September.

The changing character of so many vital features of lighting science and art, and the fluid condition of today's business emphasize the importance of keeping up-to-date on what is going on. You cannot afford to stay away.

Samuel G. Hibben, *President.*

Conference Planners

At right (left to right):

Hoyt Steele, National Conference Chairman

Ralph Raymond, Local Conference Chairman

L. E. Taylor, Chairman, Lighting Service Forum

Below (left to right):

L. E. Barbrow, Roy Palmer, R. M. Zabel — Co-Chairmen, Papers Committee

14. "A New Lead-Lag Ballast for Discharge Lamps" by C. H. Burns, H. E. Bachman, Westinghouse Electric Corporation.
15. "New Fluorescent Lamp and Ballast Design for Fast, Rapid Starting" by A. E. Lemmers, W. W. Brooks, General Electric Company.
16. "Characteristics and Applications of High-Frequency Fluorescent Lighting" by J. H. Campbell, General Electric Company.
17. "Pavement Brightness Measurements" by D. M. Finch, University of California and R. B. Marsheimer, Bechtel Corporation.
18. "Techniques for Photography of Lighted Streets" by T. Knowles, D. A. Toenjes, General Electric Company.
19. "Some Photographic Methods Applied to Photometry" by Charles Marsh, Pennsylvania State College and Consultant, Westinghouse Electric Corporation.
20. "Standard Practice of Street and Highway Lighting Sub-Committee, C. H. Reed, Chairman.
21. "The Kinorama as an Evaluator in Aviation Lighting" by F. C. Breckenridge, National Bureau of Standards, Dept. of Commerce.
22. "The Zonal Method of Computing Coefficients of Utilization and Illumination on Room Surfaces" by J. R. Jones, J. J. Neidhart, Westinghouse Electric Corporation.
23. "Control and Measure of Directional Flux at the Task" by George P. Wakefield, F. W. Wakefield Brass Company.
24. "Visibility of School Tasks" by J. M. Ketch, C. J. Allen, General Electric Company.
25. "Evaluating the Comfort and Cost of Modern Industrial Lighting" by R. D. Bradley, G. J. Tayler, Daybright Lighting, Inc.
26. "Tests Aimed at Realistic Maintenance Factors" by R. L. Oetting and J. W. Tuttle, General Electric Company.
27. "Time Versus Luminous Ceilings" by D. E. Spencer, L. F. Martin, University of Connecticut.
28. "Positioning of Directionally Adjustable Luminaires" by Merle E. Keck, Westinghouse Electric Corporation.
29. "Structural Lighting in a Modern Home" by Aileen M. Page, General Electric Co.
30. "Developments in Submarine and Ship Building Lighting" by Dean Farnsworth, U. S. Naval Medical Research Laboratory.

COMMITTEE PERSONNEL

The printed program mailed to the membership, for reasons of space limitation, did not list the hard-working committee men responsible for the tremendous job of planning and conducting such a meeting. Great credit is due the following individuals for many months of hard work in this connection.

National Technical Conference Committee

Hoyt P. Steele, Chairman, Benjamin Electric Mfg. Co., Des Plaines, Ill.

George W. Clark	Clarence B. Pederson
G. F. Dean	Ralph Raymond
James C. Forbes	Richard G. Slauer
Robert F. Hartenstein	Lee E. Taylor
A. Dexter Hinckley	A. S. Turner, Jr.
Charles N. Laupp	Marshall N. Waterman

Rolland M. Zabel

Papers Committee

Louis E. Barbrow, Co-Chairman, National Bureau of Standards, Washington, D. C.
Roy A. Palmer, Co-Chairman, Duke Power Co., Power Bldg., Charlotte, N. C.
Rolland M. Zabel, Co-Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

G. W. Beals	John O. Kraehenbuehl
Roy E. Dahlin	William P. Lowell, Jr.

Kirk M. Reid

Lighting Service Committee

Lee E. Tayler, Chairman, Detroit Edison Co., Detroit, Mich.

W. E. Folsom	Charles N. Laupp
Paul H. Hildebrand	Carl O. Martin
K. E. Hollingsworth	R. Cecil Paslay
F. P. Labey	Richard G. Slauer

F. C. Winkler
Chairman, All Chapters and Sections

Local Conference Executive Committee

Ralph Raymond, Chairman, Commonwealth Edison Co., Chicago, Ill.
Clarence B. Pederson, Vice-Chairman
Glenn G. Boyd, Secretary
Charles N. Laupp, Regional Representative

Sub-Committee Chairmen

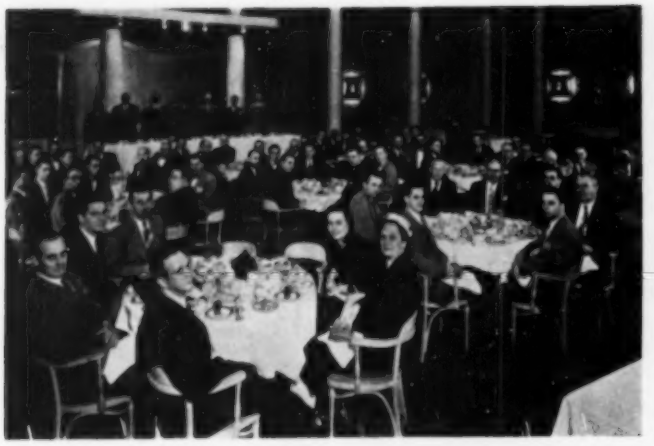
Eric H. Church, Transportation
Robert J. Diefenthaler, Finance
Ernest E. Elliott, Entertainment
Lois Fetherston, Ladies Reception
Carl J. Jensen, Hotel
Charles E. Johnson, Reception
William R. Kaiser, Attendance & Publicity
Arthur P. Larson, Lighting & Decoration
Jack K. Neuhauser, Sports
Morris M. Poe, Historian
William A. Weibel, Co-Ordinator, Chicago Section.

I.E.S. President Honored By Case Institute of Technology

An honorary degree of Doctor of Engineering was conferred on S. G. Hibben, I.E.S. President, June 7, by Case Institute of Technology in recognition of his many contributions to science and its application to important problems of our times. . . . " Acting President Elmer Hutchisson conferred the degree, saying "I greet you upon behalf of an alma mater which recognizes your career as exemplifying the worthy tradition it seeks to impart to its students. A skillful scientist and engineer, you have used your knowledge and genius in the successful service of industry and of government to create better living, greater safety for mankind and increased security for the nation."

Report on June Council Meeting

Due to the scheduling of Council meeting later in the month than usual, the summary of action was not available before the closing date for Telecast. This summary will be carried in the August issue of ILLUMINATING ENGINEERING.



KICK-OFF Luncheon at the East Central Regional Conference in Pittsburgh, May 21, featured John P. Robin, Executive Director, Urban Redevelopment of the famous Pittsburgh Renaissance, as guest speaker.

Pittsburgh Redevelopment—Theme of East Central Regional Conference

Illumination—A Dynamic Force in Pittsburgh's redevelopment—the general theme of the I.E.S. East Central Regional Conference centered around the role played by lighting in the vast redevelopment program now under way in Pittsburgh. The reconstruction program of Pittsburgh and its environs is amazing even to its citizens. It is even more amazing to visitors.

How important is lighting in this work was especially evident to visiting delegates during the evening session opening day, when the entire conference toured the city in chartered buses for an inspection trip of the city in its various stages of redevelopment. Highlight of the trip was a visit to the new Pittsburgh Airport, second largest in the country, which opened to the public the week following the Conference.

This $33,000,000 development is a city within a city. In addition to its normal airport facilities it contains a hotel, theatre, bank, public garage, night club, shops and restaurants—all with excellent illumination.

Other features of the inspection trip included visits to see outstanding lighting installations at St. Paul's Cathedral, Syria Mosque, Pitt Field House,, Carnegie Museum, as well as a tour of commercial, industrial and institutional lighting in nearby Oakland Civic Center.

Technical sessions of the conference, scheduled May 21 through May 23, were held at the Mellon Institute (across the street from the Hotel Webster Hall Conference headquarters, in itself a Pittsburgh institution worthy of an inspection trip.

The "Kick Off Luncheon" which started the Conference Wednesday noon was an outstanding innovation in conferences of this nature. Paul H. Hildebrand, Regional V-P, presided at this meeting. J. W. Schuchert, a Director of I.E.S., introduced the guest speaker, John P. Robin, Executive Director, Urban Redevelopment Authority of Pittsburgh.

Dr. Ward Harrison, President of C.I.E., and I.E.S. President S. G. Hibben, were guest speakers at the Banquet which was a feature of the evening session on Thursday. Dancing was dispensed with at this affair, in favor of these outstanding addresses. Entertainment was furnished by the Westinghouse Male Chorus.

My Most Interesting Job

East Central Region was the founding father of the now country-wide I.E.S. contest for "My Most Interesting Lighting Job." Finalists competing for East Central represetnation at the National Conference in Chicago presented their entries Friday morning. Judges, all "foreigners" to the Region were: S. G. Hibben, Bloomfield, N. J., Ward Harrison, Cleveland, Ohio, B. S. Benson, Jr., Des Plaines, Ill., R. F. Vanden Boom, Cleveland, W. H. Kahler, Cleveland, and D. P. Caverly, New York City.

First prize went to Hugh S. James, Duquesne Light Co., representing the Pittsburgh Section. Mr. James' presentation was "Planned Lighting Comes to the Syria Mosque."

Second prize was taken by Tom Hendrix, architect, representing the Eastern Pennsylvania Section for his installation at the McKinley School, Allentown, Pa. In Mr. Hendrix's absence, his entry was presented by Hugh S. (Irish) Carroll.

Third winner was G. W. Wagner, Philadelphia Electric Co., for "From Flashlight to 100 Footcandles," relighting the Baldwin Locomotive Works.

Maryland Section's entry by H. M. White, Consolidated Gas Electric Light & Power Co., Baltimore, received Honorable Mention.

The late Leo Cleary was scheduled to be the contestant for the Capital Section. In respect to Mr. Cleary, who passed away shortly before the Conference, no other installation from this Section was entered.

Chairman for the session was R. P. Teele, Chairman of Capital Section. A Panel Discusion followed the presentation, with all speakers serving on the panel and questions directed from the audience. Carl J. Long, Pittsburgh Section, served as Moderator.

Technical Sessions

An especially interesting feature of all technical sessions was the panel discussion which followed the papers. All speakers reconvened on the stage at the end of the session, and served on a panel, answering questions from the audience. In this manner, very stimulating panel sessions developed, adding to the value of the conference sessions. The program in its entirety was:

Wednesday, May 21, 1952

Morning Session

Kick-Off Luncheon. Ball Room, Webster Hall.
Chairman—Paul H. Hildebrand, Regional V-P.
Introduction of Guest Speaker, Jos. S. Schuchert, National Director I.E.S.
Guest Speaker, John P. Robin, Executive Director, Urban Redevelopment Authority of Pittsburgh.

Afternoon Session

Chairman—G. H. Maize, Pittsburgh Section.
Outline of Mellon Institute activities and inspection of the Institute, Dr. E. R. Weidlein, President of Mellon Institute.
Local Activities Committee Meeting in Webster Hall.

Evening Session

Chairman—J. Paul Warner, Pittsburgh Section.
Inspection of Greater Pittsburgh Airport.

(Continued on page 10A)

Here and There With I.E.S. Members

At the Canadian Regional Conference in Niagara Falls members inspect new constructions of the Hydro-Electric Power Commission.

Joint dinner meeting of the Aviation Lighting Committee and the Indiana Chapter in Indianapolis. Standing (l. to r.): Clarence Cornish, Director of Aviation for Indiana; Captain D. S. Little, American Airlines; D. C. Miller, General Electric Co.; Dr. C. E. Leiberknight, Kopp Glass Co.; R. C. Blatt, *Electrical World*. Seated: Randy Burleson, Universal Electric Co.; M. S. Gilbert, Technical Development and Evaluation Center; Henry I. Metz, Maintenance Engineering Div., C.A.A.

S. G. Hibben receives a gift of Rookwood Pottery (a local quality product) from Dr. Howard K. Justice, president of the Engineering Society of Cincinnati, at a joint meeting of that group and the Ohio Valley Section.

Matias J. Alfonso, left, discusses a modern Tampa church with Edward Rambusch of Rambusch Decorating Co., at a meeting of Florida Chapter where Mr. Rambusch was guest speaker.

Chicago Section's Program Committee (left) meets to review the year's activities and to draw up recommendations for next year's committee. Seated are J. H. Pierce, J. R. Chambers, B. E. Gilman, C. W. Clarkson, E. R. Lusk, C. D. Lehman, G. C. Fowler. Standing are Chick Masterson, Carl Zerson, Paul Fisher, August Eckel, Eric Church and Al Kurtson.

PANEL discussion was made up of contestants on the "My Most Interesting Lighting Job" contest, left to right: H. F. Carroll, Eastern Pennsylvania Section and proxy for Tom Hendrix; H. S. James, Pittsburgh Section; Moderator Carl J. Long; H. M. White, Maryland Section; and G. W. Wagner, Philadelphia Section.

Thursday May 22, 1932

Morning Session

Chairman—Frank Heins
Eastern Pennsylvania Section
"Light and Vision in the School and Home" by Dr. Henry S. Kane, Jr., Pittsburgh Optometric Society.
"Progress in Office Lighting" by W. H. Kahler, Westinghouse Electric Corp.
"Progress in Store Lighting" by D. P. Caverly, Sylvania Electric Products Inc.
Panel Discussion with all speakers of morning serving on panel and questions directed from the floor. J. M. Asher, Maryland Section, Moderator.
Luncheon—Ballroom, Hotel Webster Hall.

Afternoon Session

Inspection Tour of Pittsburgh.

Evening Session

Chairman—N. C. Warner, Pittsburgh Section.
Banquet and entertainment—Ballroom, Hotel Webster Hall. Informal dress.
Guest Speaker: Dr. Ward Harrison, President, Commission Internationale de l'Eclairage.
Guest Speaker: Sam Hibben, National President, Illuminating Engineering Society.

A complete listing of the National Officers of the Society and the Officers and Boards of Managers of I.E.S. Sections will be published in the August issue of ILLUMINATING ENGINEERING.

Friday, May 23, 1932

Morning Session

Chairman—R. P. Teele, Capital Section.
Presentation by Winners of Contest "My Most Interesting Lighting Job"
H. M. White, Consolidated Gas Electric Light and Power Co., Winner of Baltimore Section.
G. W. Wagner, Philadelphia Electric Co., Winner of Philadelphia Section.
H. S. James, Duquesne Light Co., Winner of Eastern Pennsylvania Section.
Panel discussion with all speakers serving on panel and questions directed from the audience. Carl J. Long, Pittsburgh Section, Moderator.

Afternoon Session

Chairman—P. B. Thorne, Philadelphia Section.
"Analysis of Typical Industrial Systems"—B. S. Benson, Jr., Benjamin Electric Manufacturing Co.
"Protective Lighting for Industry"—by A. B. Winters, Revere Electric Company.
"Inspection Problems and Solutions," by R. F. VandenBoom, Nela Park, General Electric Company.
Panel discussion with all speakers serving on panel and questions directed from audience. E. D. Altree, Pittsburgh Section, Moderator.
Awards to winners of "My Most Interesting Job" Competition.

COMMITTEE PERSONNEL
EAST CENTRAL REGIONAL CONFERENCE

Paul H. Hildebrand, Regional V-P.
G. H. Maize, General Chairman
J. B. Rhea, Secretary

J. M. Asher	R. P. Teele
F. E. Heins	N. C. Warner
A. A. Paulus	H. S. James

Registration Committee
Chairman, B. W. Townsend, General Electric Co.

Publicity Committee
Chairman, F. B. Mahon, Duquesne Light Co.

Program Committee
Chairman, H. R. Jones, West Penn Power Co.

Entertainment Committee
Chairman, H. J. Mazur, Westinghouse Electric Corp.

Transportation Committee
Chairman, A. R. Hampsey, Jr., Duquesne Light Co.

Finance Committee
C. M. Cryder, General Electric Co.
Carl J. Long, Consulting Engineer
Harold D. Siler, Pittsburgh Reflector Co.

Arrangements Committee
Chairman, C. D. Miller, Duquesne Light Co.

Reception and Information
Chairman, C. B. Swann, Pittsburgh Reflector Co.

Inspection Tour Committee
Chairman, E. J. Kelly, Duquesne Light Co.

Occupational Vision Studied At Illinois Summer Workshops

Specialists in the fields of occupational vision and optometry are taking part in the summer workshops being conducted at Northern Illinois College of Optometry, July 14-23.

Dr. Richard Feinberg, dean of the College, is directing the workshop in occupational vision, July 14 through 18, and one of the principal lecturers is R. J. Diefenthaler, district engineer of General Electric's Lamp Division, and also president of the I.E.S. Chicago Section's Study Club.

Other lecturers in this workshop are Dr. Felix Koetting, specialist in motor vehicle drivers' vision; Dr. Elmer H. Westland, Chairman of A.O.A.'s Occupational Vision Committee; R. A. Sherman, director of the Department of Occupational Vision, Bausch and Lomb Optical Co.; Dr. Frederick Kushner, Chairman, A.O.A. Occupational Vision Committee; Dr. Carl Shepard, Director of Research at Illinois College, and William Cameron, Director of the Department of Occupational Vision, American Optical Company.

The Optometry Workshop, July 19-23, features visits to the Illinois Eye and Ear Infirmary, University of Illinois and to the Museum of Science and Industry, as well as lectures by staff members.

Street and Highway Safety Lighting Full Day Clinic in Chicago

There was a record attendance of 248 at the all-day, all-evening sessions of the Clinic on Street and Highway Safety Lighting, held May 23 at the Chicago Lighting Institute. The clinic was sponsored by the Chicago Section, I.E.S., and the Chicago Lighting Institute with the cooperation of local safety groups. Francis D. Wyatt, Chicago Park District, was chairman of the technical sessions which had the following program:

Morning

Nomenclature and Types of Distribution — Stuart R. Williams, Holophane Co., Inc.
Light Sources and Auxiliary Equipment — Kirk M. Reid, General Electric Co.

(Continued on page 12A)

X
You Have Registered!
CHICAGO IN '52
EDGEWATER BEACH HOTEL
SEPTEMBER 8-12
NATIONAL TECHNICAL CONFERENCE

(Continued from page 10A)

Luminaires and Mounting Equipment—W. H. Edman, Line Material Co.

Wiring and Circuits, Panel Discussion, J. L. Gustat, Public Service Co. of Northern Ill., Chairman; Eric Smith, Edwin Hancock Engineering Co.; Carl Cassidy, General Electric Co.; William Miller, Chicago Park District; Howard Ilgner, City of Milwaukee.

Afternoon

Control and Operating Equipment—J. L. Cissel, South Bend Current Controller.

System Design, Panel Discussion—R. M. Sweetland, General Electric Co., Chairman; Kirk Reid, General Electric Co.; J. L. Cissel, South Bend Current Controller; Stuart Williams, Holophane Co., Inc.

System Maintenance—H. F. Ilgner, City of Milwaukee.

Let's Add It Up—Lloyd M. Johnson, Commissioner of Streets and Electricity, City of Cicero.

The evening session was a symposium of brief talks on Lighting the Way for a Better Chicagoland, with Virgil Gunlock, Commissioner of Subways and Super Highways for Chicago, serving as chairman.

Lighting for Accident Reduction—R. G. Wilcox, National Safety Council.

Lighting as an Aid to Crime Prevention—Carl Soderlin, Chief of Police, River Forest, Ill.

Lighting as an Aid to Traffic Movement—J. Stannard Baker, Traffic Institute, Northwestern University.

How Good Lighting Can Reduce Automobile Losses—William J. Davis, National Automobile Theft Bureau.

Business Follows Light—Chalmers O'Brien, Carson Pirie Scott & Co.

A Brighter Future—Kirk Reid, General Electric Co.

The fact that the clinic was reaching the right people is evidenced by an analysis of the attendance—a record in itself. Of the 248 attending, 27 per cent were representatives from State, County, City and Village governments and 22 per cent from public utility companies. The breakdown was:

State, County, City and Village Officials—27%
Public Utility Companies—22%
Lighting Equipment Mfgrs.—20%
Electrical Contractors—10%
Consulting Engineers and Architects—6%
Electrical Wholesalers—5%
Trade and Technical Groups—4%
Realtors—2%
Miscellaneous (including the press)—4%

The local groups who cooperated in the planning of the clinic were the Chicago Motor Club, Chicago Real Estate Board, Citizens' Traffic Safety Board, Cook County Traffic Safety Foundation, National Automobile Theft Bureau, Traffic Institute of Northwestern University and the Junior Association of Commerce.

Design Competition for Vocational Students Sponsored by N. Y. Residence Lighting Forum

Eighty five dollars in cash prizes, in addition to four home lighting books, went to teenage winners of an especially constructive contest conducted this Spring by the New York Section Residence Lighting Forum. With the cooperation of the New York City Board of Education, the I.E.S. group sponsored a design competition among students of the city's vocational high schools. The contest received such response that the Board of Education plans to feature a similar contest next year for all the city's schools, under I.E.S. auspices. Some 420 designs were submitted in this year's contest, from 19 vocational schools.

The problem given the students to solve involved the lighting design of a specified home, blueprints of the area accompanying each problem. The contestants not only specified the lighting for the rooms, but in many cases offered designs of the lighting equipment as well. Many of the entries showed deep study and research into residence lighting, indicating that the principles of good lighting were being absorbed by a completely new group of young people.

Winning installations were submitted by the following students:

First prize—$50.00—Marino Bevilacqua, of Machine & Metals Trades High School.

Second prize—$20.00—Sixto Gomez, of Machine & Metals Trades High School.

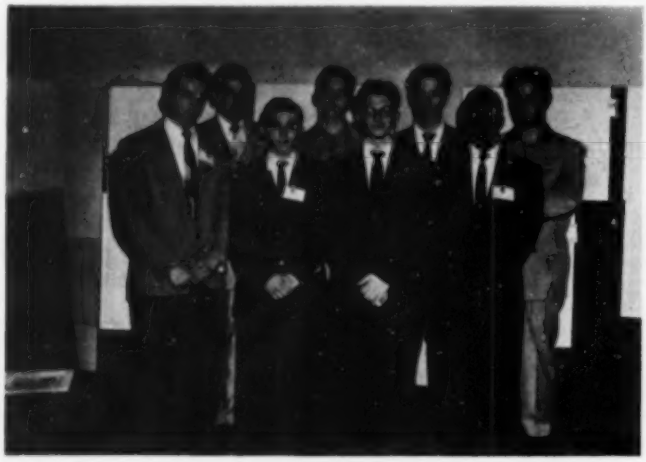
Third prizes—$5.00 each went to:
John Palmer, Williamsburg Vocational H. S.
Luke J. Minerva, George Westinghouse Vocational H. S.
M. J. Varela, George Westinghouse Vocational H. S.

Four entries receiving honorable mention were submitted by Joseph Nicoles, East New York Vocational; Robert Pearson, Williamsburg Vocational; Arnold Cooper, Machine & Metals Trades School; Sal Matina, George Westinghouse Vocational H. S.

Credit for the outstanding success of the project goes particularly to Dr. Frederick Pertsch, Associate Superintendent of N. Y. Schools, and Mrs. Dorothy Thornton, Supervisor of Industrial Design of the N. Y. Board of Education, who arranged details of the project and carried through plans for city-wide participation. Thomas Smith Kelly, Lighting Consultant, and Miss Lillian Eddy, home lighting specialist with General Electric, New York district, were co-chairmen of the Forum Committee which planned and conducted the competition. Together with vocational school teachers they also served as judges of the designs submitted.

The prizes were presented at a tea meeting held June 3 at the Central High

(Continued on page 15A)



STUDENT WINNERS of the design competition held by the New York Residence Lighting Forum are: Front row, Marino Bevilacqua, Arnold Cooper, Joseph Nicoles, Robert Pearson; back row, Sal Matina, Sixto Gomez, Luke J. Minerva, Manual J. Varela. Missing from photo is John Palmer. These winners were chosen from a total of 420 entries.

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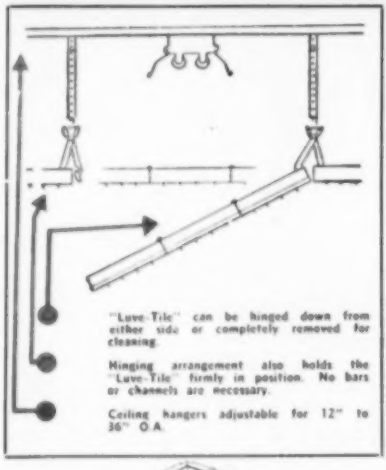
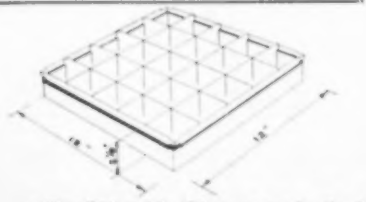
Wilson "Luve-Tile"


"Luve-Tile" can be hinged down from either side or completely removed for cleaning.
Hinging arrangement also holds the "Luve-Tile" firmly in position. No bars or channels are necessary.
Ceiling hangers adjustable for 12" to 36" O.A.



• "Luve-Tile" modular 12" squares may be clipped together to form door sections.

THE BEAUTIFUL NEW ILLUMINATED CEILING

• Wilson "Luve-Tile" presents to engineers and design-conscious people the practical tool to ideal lighting. The basic unit consists of a one foot square louvered panel, moulded from Monsanto styrene plastic. Each panel weighs 13 ounces and contains 25 cubes which provide 45° lengthwise and crosswise shielding. Luve-Tile ceilings provide lower ceiling brightness, especially for higher intensities, from 50-foot candles up.

• Luve-Tile is available in white, pastel pink and blue and as such a variety of interesting and practical coloured ceiling patterns are possible. A variation of the pattern effects may be obtained by the use of coloured lights.

• A simple hinging arrangement as illustrated provides easy maintenance. Dirt collection is less rapid or noticeable than with other types of luminous ceilings. Luve-Tile is rigid to handle, light in weight, and simple to remove and wash.

For complete details and prices, write for illustrated catalogue.

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In Canada: 280 Lakeshore Road, Toronto 14, Ontario

(Continued from page 12A)

School of Needle Trades, New York City. Dr. Pertsch addressed the group, expressing his enthusiasm in the lighting contest, and his wish to see it extended to all the city's schools. The prize presentation was made by Mr. Kelly and Miss Eddy, Co-chairmen of the Design Competition Committee. Miss Edith Buchholtz, Chairman of the New York Section Residence Lighting Forum, presided at the meeting.

Seeing in School — Theme Of A.O.A. Conference

Reports on research in the prevention and correction of seeing problems of school children were the substance of the fifty-fifth annual Congress of the American Optometric Association, in Miami Beach, Fla., June 8-11.

S. K. Guth, Director of Lighting Research, General Electric Co., gave the illuminating engineer's viewpoint of the necessity of considering the entire visual environment, and James D. MacConnel of Stanford University's School of Education declared that school buildings should be constructed, lighted, furnished and decorated to fit the scientifically determined needs of the whole child.

An interesting development in optometry is the new visual recognition standard chart, using arabic numbers, to supersede the conventional Snellen letter chart for eye examinations. The standard and chart design are the results of many years of experimentation by a committee headed by Dr. Glenn A. Fry of Ohio State University School of Optometry.

More than a thousand delegates from every state in the country attended the four-day conference.

Aviation Lighting Committee Meets with Indiana Chapter

A new "first" has been made—a joint meeting of an I.E.S. technical committee and an I.E.S. Chapter, when the Aviaiton Lighting Committee held its Spring Technical Conference in Indianapolis and held a joint dinner meeting with the Indiana Chapter.

Attendance was about 80 for these meetings, which took place at the C.A.A. Technical Development and Evaluation Center, Weir Cook Municipal Airport. The Thursday program was as follows:

Development of a Taxi Guidance Sign System —B. A. Hemelt, C.A.A. Office of Airports.

Development of Taxiway Guidance Signs— M. S. Gilbert, C.A.A. Technical Development and Evaluation Center.

(Continued on page 16A)

LIGHTING CALENDAR

Society Events

July 10, 1952 — Meeting of I.E.S. Council Executive Committee.

September 8-12, 1952 — Illuminating Engineering Society, National Technical Conference, Edgewater Beach Hotel, Chicago, Ill.

Industry Events

July 6-11, 1952 — New York Lamp Show, Hotel New Yorker, New York, N. Y.

August 19-22, 1952 — Pacific General Meeting, American Institute of Electrical Engineers, Phoenix, Ariz.

September 8-10, 1952—American Standards Association's Third National Standardization Conference, Museum of Science and Industry, Chicago, Ill.

September 8-11, 1952 — Institute of Traffic Engineers, Annual Meeting, Hotel Sherman, Chicago, Ill.

September 29 - October 2, 1952 — Annual Convention, International Municipal Signal Association, Inc., Hotel Statler, Boston, Mass.

October 1-3, 1952—Canadian Electrical Manufacturers Association, 8th Annual Meeting, General Brock Hotel, Niagara Falls, Ontario.

October 1-4, 1952 — 17th Annual Conference, International Association of Electrical Leagues, Radisson Hotel, Minneapolis, Minn.

October 7-9, 1952 — Pacific Coast Regional Restaurant Convention and Exposition, Biltmore Hotel, Los Angeles, Calif.

October 13-17, 1952—Fall General Meeting, American Institute of Electrical Engineers, New Orleans, La.

October 20-21, 1952 — National Farm Electrification Conference, Hotel Statler, Detroit, Mich.

October 20-24, 1952 — 40th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

November 10-13, 1952 — National Electrical Manufacturers Association, Haddon Hall Hotel, Atlantic City, N. J.

November 17-19, 1952 — 39th National Foreign Trade Convention, Waldorf-Astoria Hotel, New York, N. Y.

November 19, 1952 — 34th Annual Meeting, American Standards Association, Waldorf-Astoria Hotel, New York, N. Y.

January 19-23, 1953 — Winter General Meeting, American Institute of Electrical Engineers, New York, N. Y.

March 9-12, 1953—National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

Week of May 24, 1953 — 45th Annual Convention, National Association of Electrical Distributors, Stevens Hotel, Chicago, Ill.

June 29 - July 3, 1953 — Summer General Meeting, American Institute of Electrical Engineers, Atlantic City, N. J.

August 18-21, 1953 — Pacific General Meeting, American Institute of Electrical Engineers, Vancouver, B. C.

September 21-26, 1953 — 25th Jubilee Meeting, International Association of Electrical Inspectors, Edgewater Beach Hotel, Chicago, Ill.

November 9-12, 1953 — National Electrical Manufacturers Association, Haddon Hall Hotel, Atlantic City, N. J.

NEWLY INSTALLED Testing Equipment in the laboratory at the C.A.A. Technical Development and Evaluation Center, Indianapolis, is inspected by members of the I.E.S. Aviation Lighting Committee.

(Continued from page 15A)

Testing Taxiway Lighting Systems—*Dr. Jesse Orlansky, Dunlap and Associates,* who have been studying this problem for the Navy Bureau of Aeronautics.

Comments from Subcommittee on Taxiway Lighting—Martin A. Warskow, Chairman.

After an inspection of the taxiway lighting systems at the center and a break for lunch, the program continued with

USAF High Intensity Runway and Overrun Lights—Major P. H. Greenlee and G. M. Kevern, Wright Air Development Center.

Report on C.I.E. Signal Color Program—F. C. Breckenridge, National Bureau of Standards.

Arrangements were made for those interested to go to the Indianapolis Speedway to witness qualifying speed trials and other activities preparatory to the famous 500 mile Memorial Day Race.

The Indiana Chapter joined the committee for cocktails and a smorgasbord dinner in the Mirror Room of the Marott Hotel, after which movies of airplane approaches and landings at several airports and with various ground aids were shown by Captain D. S. Little of American Airlines. Dr. F. C. Leberknight, Kopp Glass Co., spoke on "Relationship Between Glass Color Filter Temperature and Transmission."

The Friday morning session consisted of the following subjects:

Considerations in Aircraft Instrument Lighting Design—M. K. Laufer, Grimes Manufacturing Co.

Airport Lighting Abroad—J. F. Angier, C.A.A. Representative to I.C.A.O.

A Study of the Visibility and Glare Range of Slope Line Approach Lights—H. J. Cory Pearson, C.A.A. Technical Development and Evaluation Center.

Roundup Report on Latest Status of Approach Lighting Situation—R. C. Blatt, Moderator.

French Association of Illuminating Engineers Hold Lighting Congress in Toulouse

A most successful series of conferences was conducted April 29 through May 3 by the French Association of Illuminating Engineers (A.F.E.) in Toulouse, France. The meeting was held in Toulouse for the first time in the history of the Association to coincide with the city-wide celebration of "Light Week" in which the entire population of the city and surrounding area participated. On the basis of the technical meetings as well as the artistic public lighting demonstrations, the program was a complete success.

Included in the 300 registered delegates were 25 foreign delegates from Belgium, Spain, Great Britain, Holland, Italy, Switzerland and the United States. The American delegation included C. A. Atherton, General Secretary of C.I.E., E. W. Commery of the Lamp Department, General Electric Co., Nela Park; A. H. Manwaring, Vice-President of I.E.S., and Marshall Waterman, Westinghouse Electric Co., Bloomfield, N. J. A special session on Lighting in the United States was a feature of the conference. Mr. Henry Maisonneuve, Member Emeritus of I.E.S. presided at this session; Mr. J. J. Chappat and Mr. L. Gaymard, both foreign members of the American I.E.S. made contributions to the discussion. During this session, Mr. Atherton spoke on "Organizations in the United States for expansion of the Lighting Market." Mr. Commery presented a paper on "Improvement and Simplification of White Fluorescent Lamps in the United States" and Mr. Waterman presented a paper (in French) on "Developments in Mercury Lamps and Applications in the U.S.A." Mr. Manwaring, who attended the conference as official representative from this Society spoke on "The activities of the American I.E.S."

Other sessions of the conference were dedicated to the following subjects: Technique of Lighting—Lighting of Public Thoroughfares—Exterior Lighting—Various applications of lighting, and Development of lighting. Twenty-eight reports were presented during those meetings, of which many were the subjects of interesting discussions.

The additional activities, grouped under the theme of "Light Week," included primarily the lighting of thirty historical monuments and the installation of new public lighting devices in approximately fifteen streets located in the center of the city.

Toulouse, known as the "pink city" because it is built primarily of bricks which give it a characteristically warm color under the balmy Southern sunlight, is a very old city of beautiful churches and superb private "hotels," which are houses built by rich merchants and celebrities during the Renaissance. The combination of brick and stone give these buildings a picturesque appearance, but unfortunately the low reflection factor of the walls created some problems for the engineers assigned to lighting them by means of spotlights.

Many of the hotels contain elaborate inside courts and some of them are not generally open to the public. The population of Toulouse has thus had a new opportunity to view those houses under lighting which gave them a new and festive appearance.

In the report which he made on public lighting, Mr. P. Prat, chief city engineer, recalled that in 1783, the "Capitouls," that is, the members of the Toulouse city council, had recommended that the brick facades be whitewashed. The reasoning behind that decision was recorded as follows:

"White being the result of the mixing of the other colors, and having therefore the property to reflect them all, it naturally follows that this property must increase and render more striking the moonlight and the illumination of street lights."

Thus, as early as that period, the "Capitouls," acting as true illuminating engineers, were taking into consideration the reflection factor of buildings.

The engineers were nevertheless happy

(Continued on page 18A)

PRESIDING OFFICERS at the American Session of the Toulouse meeting are, left to right, Jean J. Chappat, Henry Maisonneuve and L. Gaymard.

Equity Savings & Loan Company, Cleveland, Ohio. The main office and three private offices are lighted by Wakefield Ceilings, incorporating PLEXIGLAS diffusers. Architects: Dalton-Dalton Associates, Cleveland. Installed by Parker Electric Company, Cleveland. Wakefield Ceilings are produced by The F. W. Wakefield Brass Company, Vermilion, Ohio.

Lighting . . . Air Diffusion . . . Sound Control . . .

Combined in a Luminous Ceiling

The Wakefield Ceiling shown above, with its corrugated PLEXIGLAS diffusing panels, combines three functions in a single installation.

- Mounted wall to wall beneath fluorescent tubes, the acrylic plastic panels provide high level, low brightness, evenly diffused illumination.
- Conditioned air from the space above the luminous ceiling is delivered into the room through the openings at the edges of the corrugated diffusers. The multiple openings insure an even distribution of air, with elimination of drafts on customers and employees.
- The simple framework for the PLEXIGLAS also supports acoustical baffles which absorb sounds from the work area.

This Wakefield method of combining air diffusion and sound control with the *best* in lighting—using PLEXIGLAS acrylic plastic—can reduce building construction and operation costs. In addition there is the advantage of duct-free, fixture-free appearance.

We will be glad to send you details about the installation shown above, and tell you how PLEXIGLAS may solve *your* lighting problem.

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(Continued from page 16A)

to note that progress made in public lighting has enabled the present major to abolish that decree and to require that any facade maintenance include the removal of whitewash, so as to return to the buildings their proper appearance of pink brick.

Other events which were a feature of the congress included a contest of illuminated layouts among the city retailers; an educational exhibition of Lighting, where the principal manufacturers displayed their materials; and to conclude, a photography contest based on the illuminated monuments.

As indicated by Monsieur Andre Claude, President of the A.F.E., this congress has had a two-fold success: first among the technicians, because of the interest of the subjects covered during the meetings; second, among the residents of Toulouse, who have lived an entire week under the theme of Lighting.

IT SEEMS TO ME

Daylighting in Classrooms

This relates to Mr. W. J. Arner's coments, of my paper "Daylighting in Classrooms' (January 1952), that were published in the May 1952 issue under "It Seems to Me."

Apparently there is considerable confusion as to the prevalence of certain exterior illumination conditions and the intensities that pertain. All of us have observed that sky conditions vary from the cloudless through a large variety of cloud formations to the overcast. The cloudless and the overcast skies occur less frequently than other types because they represent unique conditions. Logically, brightness distribution data for cloudless and overcast skies appear in the literature because such skies are sufficiently static, timewise, to allow accurate measurement. The most extensive data of this kind that have been published are those of Kimball and Hand to which Mr. Arner refers. Some of these data represent measurements of sky conditions in Chicago and Washington, D. C. and the remainder were obtained from calculations based on the actual measurements. Although they are extremely valuable these data do not represent an extensive survey of all exterior illumination conditions.

Because of this need of more extensive measurements the Daylighting Laboratory during the past eighteen months has been making continuous measurements of exterior illuminations in Ann Arbor. The data, collected with corrected photocells and an automatic recorder, give the illumination of north, south, east and west vertical surfaces due to direct light from sun and sky; that is, the photocells do not receive ground reflections.

It is on the basis of these data that I selected an exterior vertical surface illumination of 1000 footcandles as being representative of an overcast sky; an overcast day being characterized as one having cloud formations sufficiently dense to provide substantially the same illumination on all exterior vertical surfaces and a zenith brightness approximately $2\frac{1}{2}$ times the horizon brightness.

Mr. Arner says that 704 footcandles is the maximum vertical surface illumination due to overcast sky recorded for Dallas, Texas over a two-year period. I presume that he is referring to the work of R. L. Biesele, Jr. In his article "Daylight in Classrooms" published in ILLUMINATING ENGINEERING, July 1950, Professor Biesele reports on one overcast sky condition that showed an exterior vertical surface illumination of 911 footcandles. In his article, "Daylight in Classrooms — Multilateral Lighting" published in ILLUMINATING ENGINEERING, April 1951, Professor Biesele reports on seven overcast sky conditions that showed exterior vertical surface illuminations ranging from 211 to 1530 footcandles. Of these eight overcast sky conditions five of them showed an illumination greater than 704 footcandles. With one exception these exterior illuminations had to be scaled down to the 500 footcandles that is considered to be representative of an overcast sky. The 211-footcandle condition Professor Biesele referred to as being for the darkest overcast that he had encountered.

I think that all of this indicates that 500 footcandles is too low to be representative of exterior vertical surface illumination due to overcast sky.

Mr. Arner also comments on the fact that the minimum task illumination in the classrooms that I reported on was below the recommended 30 footcandles. He did not have any comments to make on the quality of the daylight although it is generally agreed that quality is much more important than quantity in a good visual environment. This bears out what I said in the article "that there is still a tendency to minimize quality and talk principally of quantity."

The direct reading brightness meter that was used has a field of view of 0.01 steradians. Thus, at any distance in a classroom greater than 80 inches it includes the entire face of an eight-inch glass block including the mortar joint.— R. A. BOYD, *Research Physicist, University of Michigan, Ann Arbor, Mich.*

CHARTER MEMBERS of the Student Branch, I.E.S., at the University of Miami are, front row in the usual order, R. S. Newman; Herbert Weisbrot, Secretary; R. A. Arpante; A. W. Sanders, Vice-President; J. B. Gibson; R. T. Dunn, and Prof. Jackson S. Sells, Faculty Advisor. Back Row, H. E. McCall; Gabriel Weingarten; Howard Lefkowitz, Treasurer; R. A. Zalonga; C. J. Minnet; G. T. Morgan; J. K. Hughes, President. D. L. McMillen, not in photo.

BOOKS AND PAMPHLETS

*Books whose reviews are marked * are available for inspection at Headquarters Office, Technical Dept.*

***Primer of Electronics and Radiant Energy** by Don Caverly, Second Edition published 1952 by McGraw-Hill Book Company, New York; 352 5¼ x 8 inch pages, 202 illustrations; $5.50.

The author uses the term electronics

(Continued on page 21A)

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While the city sleeps . . .

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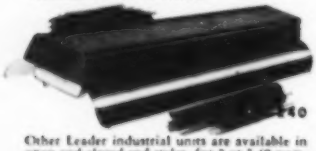
NEW *Diffuser Unit*—Designed to modify the contrast between lighted work areas and upper dark areas. 75% indirect lighting component. All-steel construction. For 2 or 3 40-watt lamps, in open or closed end models. Porcelain reflector if desired.



Other Leader industrial units are available in open and closed end styles, for 2 or 3 40-watt, 2 85-watt, for 2, 3 or 4 slimline lamps. Rugged construction, many convenient features, choice of mounting. Write for complete information. No obligation.

. . . industry hums, with the production of vital defense materiél, the manufacture of more and better products to meet America's expanding needs. Lighting plays an indispensable part in maintaining production at continuously high levels . . . and Leader plays an importat role in providing proper lighting for industrial production. The Leader line includes fixtures for all general and many specialized industrial requirements . . . and all units afford top performance, ease and flexibility of installation, economy in first cost and maintenance.

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Campbell-Leader, Ltd.—Brantford, Ontario, Canada

(Continued from page 18A)

to include all applications of electricity and magnetism: instrumentation, motors, and transformers as well as electron tubes and their circuits. This book was written especially for non-technical people with a curiosity about the electrical equipments so widely used today. In the words of the author it is "a digest of the very basic principles involved in the study of how electrons, protons, neutrons, and other composite atomic particles behave and are controlled and how the radiant energy attending their release or disturbance in atoms is utilized.' It is a much revised, extended version of Mr. Caverly's 1943 *Primer of Electronics*.

Beginning with a description of atomic structure the author explains the fundamentals of electricity and magnetism; then progressing to all types of radiant energy from subsonic vibrations through radio, television and radar to light (55 pages including infrared and ultraviolet), gamma rays and atomic energy; dealing in the final hundred pages with electron tubes, light sources (30 pages), and sources of other radiant energy over the entire electromagnetic spectrum.

The Trend Toward Better Lighting in Maine Schools, described as a pictorial booklet on current practices in artificial illumination, shows the lighting in classrooms, auditoriums, home economics rooms in Maine grade schools, high schools and colleges, using both incandescent and fluorescent. Attractively done with large illustrations and heavy coated paper, this booklet was prepared and edited by the Lighting Department of the Central Maine Power Co., Augusta, Maine.

Lighting for Industry, new 96-page booklet published by the Holophane Company, Inc., 342 Madison Ave., New York 17, N. Y., is divided into three sections. The first is general, covering economics of industrial lighting, lighting calculations, lamps, glare, economic analysis of incandescent-mercury and fluorescent systems, and in-service illumination values. The second section covers specific indoor industrial areas and the third deals with specific outdoor industrial areas. The booklet is illustrated with photos, diagrams and drawings.

Bright Future, a new full-color motion picture on residential lighting, is intended for use by such groups as home builders, contractors, retailers, wholesalers, electric utilities, manufacturers, schools, service and women's clubs. The 29-minute movie presents the change that proper lighting made on three homes, transforming gloom to cheer. The film is being made available through the 35 sales districts of the Lamp Division of the General Electric Company.

Better Than Kings, 28-minute, "live-action," full-color movie directed to builders and home owners, dramatizing the conveniences of "electrical living." The advantages of adequate wiring and electrical appliances are entertainingly demonstrated by the film's story—flash-back comparisons with the "good old days." Suitable for showing to social and service clubs, professional groups, home economic students, etc., the film is available on a loan or outright purchase basis. Further information about "Better Than Kings" may be obtained from Better Homes Bureau, Westinghouse Electric Corp., 401 Liberty Ave., Box 868, Pittsburgh 30, Pa.

ABOUT PEOPLE

Marshall N. Waterman has been named assistant manager of commercial engineering for Westinghouse Electric Corp.'s Lamp Division. Mr. Waterman, a prominent I.E.S. member, is also member of the U. S. Committee of the C.I.E., and active in all phases of the lighting art.

George S. Evans has been appointed manager of the Michigan Lamp Sales Division of Westinghouse Electric Corp., Lamp Division, and will have headquarters in Detroit. He has been in the company's research, engineering, production and sales departments since he joined as a member of the Graduate Student Course sixteen years ago. Mr. Evans succeeds **H. A. Kinley**, who is appointed staff assistant to the manager of the Central Sales District.

At a recent meeting of the board of directors of Jefferson Electric Co., Bellwood, Ill., **James M. Bennan** was elected Chairman of the Board and reelected as President of the company.

OBITUARIES

William J. Serrill, past-president of the Illuminating Engineering Society, died May 27. Mr. Serrill, who joined the Society in 1909, also served several terms as chairman of the Philadelphia Section and in 1916 was elected National President. Among other activities, Mr. Serrill served on the Committee on Nomenclature and Standards, the Committee on Industrial and School Lighting and the Committee on Lighting Legislation. For the years 1928-1930, he was president of the American Standards Association.

In 1929 he retired from his position as head of the planning department of United Gas Improvement Co., Philadelphia, with whom he had been employed since 1885. In recognition of his distinguished contributions to the Society and the lighting industry, Mr. Serrill was elected to the grade of Member Emeritus.

James C. Daley, one of the founders of the Jefferson Electric Co., died May 15 of a heart attack. Chairman of the Board of this company since 1947, Mr. Daley did much to pioneer in fluorescent ballasts and transformers.

NEW MEMBERS

At the meeting of the I.E.S. Council, held in Swampscott, Mass., on June 18, 1952, the following were elected to membership:

ALAMO CHAPTER

Associate Members:

Collins, M. A., J. W. Beretta Engineers, Inc., San Antonio, Texas.

Payette, W. F., Kelly Air Force Base, Kelly Field, Texas.

Wright, J. C., Paul Wright Electric Co., San Antonio, Texas.

ARIZONA CHAPTER

Members:

Nelson, V. A., General Electric Supply Co., Phoenix, Ariz.

Smith, C. B., Arizona Public Service Co., Phoenix, Ariz.

Associate Member:

Blizzard, W. A., DeBerge Electric Co., Phoenix, Ariz.

BRITISH COLUMBIA SECTION

Associate Members:

Anderson, A., British Columbia Electric Railway Co., Vancouver, B. C.

Wadsworth, W. D., Gibbins Rd., Duncan, B. C.

CAPITAL SECTION

Associate Member:

Bang, B. A., Reed Research Inc., Washington, D. C.

CAROLINAS CHAPTER

Member:

Pancoast, H. R., Bryant Electric Co. Inc., High Point, N. C.

Associate Members:

Pierce, R. A., Champion Lamp Works, Lynn, Mass.

Simmons, N. L., General Electric Co., Columbia, S. C.

Williams, G. W., Jr., Bryant Electric Co., Inc., High Point, N. C.

CENTRAL ILLINOIS CHAPTER

Associate Member:

Smith, S. W., Beling Engineering Consultants, Peoria, Ill.

CENTRAL NEW YORK SECTION

Member:

Wilson, P. F., Corning Glass Works, Corning, N. Y.

Associate Members:

Grant, F. L., Grant & Farber, Inc., Syracuse, N. Y.

Stanton, C. C., 144 Seneca St., Corning, N. Y.

(Continued on page 22A)

(Continued from page 21A)

CHICAGO SECTION

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Wigert, J. W., Westinghouse Electric Corp., Cleveland, Ohio.

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Jack, G. N., Rayfax Electric Supplies, Inc., Tampa, Fla.
Schad, Ray, Richard A. Belsham, Orlando, Fla.
Sgro, Daniel, Daniel Sgro & Co., Tampa, Fla.
Willert, A. R., Willers Electric Co., Tampa, Fla.

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Rosenthal, A. S., Rensselaer Polytechnic Institute, Schenectady, N. Y.
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Curtis, G. V., Hydro Electric Design Branch, Portland, Ore.
Klawa, F. A., Wally Matson, Portland, Ore.
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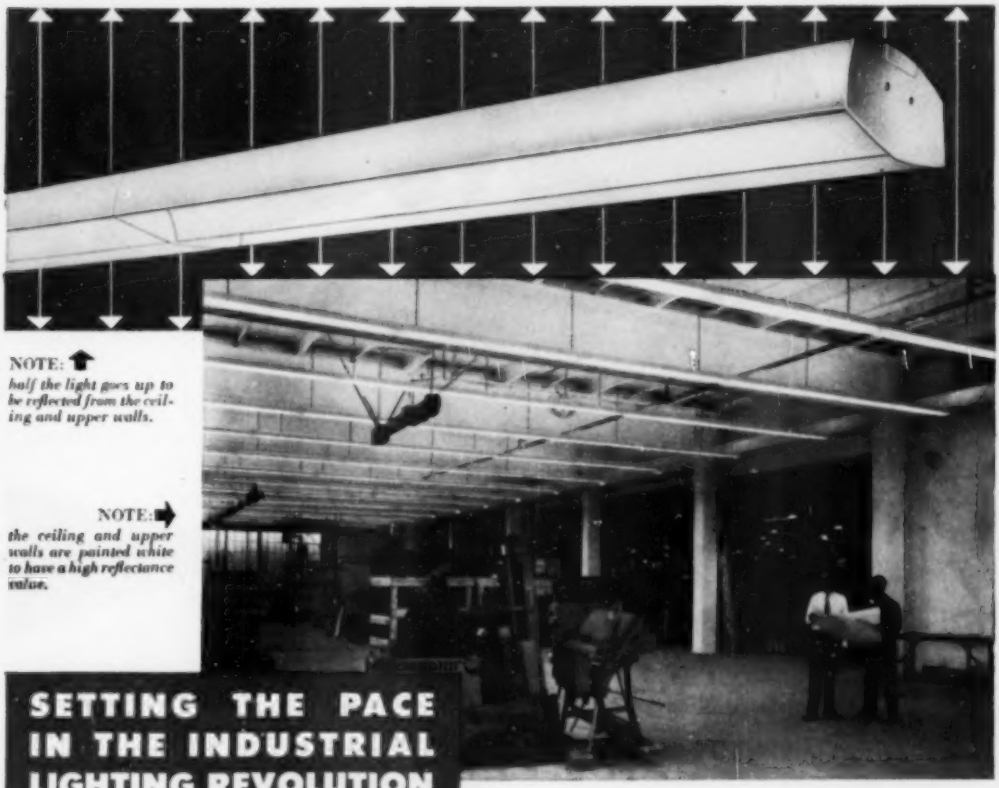
Student Member:

Brigman, J. A., Oregon State College, Corvallis, Ore.

(Continued on page 32A)



NOTE: ⬆
half the light goes up to be reflected from the ceiling and upper walls.

NOTE: ➡
the ceiling and upper walls are painted white to have a high reflectance value.

SETTING THE PACE IN THE INDUSTRIAL LIGHTING REVOLUTION

THE WAKEFIELD INDUSTRIAL PACEMAKER

A revolution is taking place in factory lighting—and sparking the revolution is the Wakefield Industrial Fluorescent Pacemaker.

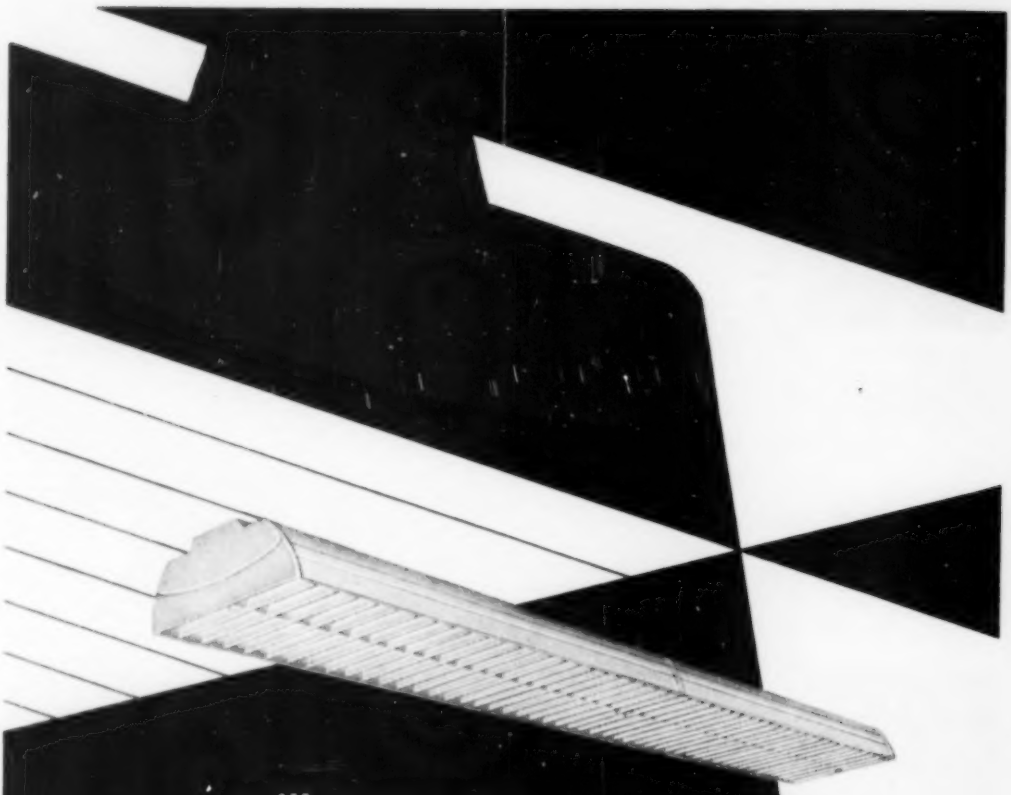
Study the photo above to see the revolution in action. In the foreground is a new addition to an old plant, lighted by Wakefield Industrial Pacemakers. In the background is a glimpse of the old plant, a gloomy cavern by contrast, lighted in the old way by old style industrial fixtures.

In the new plant area, continuous rows of Wakefield Industrial Pacemakers send half the light up to be reflected from ceiling and upper walls. That's step one in the revolution—a luminaire that has a substantial upward lighting component. Step two is to paint the ceiling and walls white to give them a high reflectance value. Result: a bright, comfortable, overall visual environment, markedly free from glare, shadows and sharp brightness contrasts, in which people work better, faster and more accurately and are less tired at the end of the shift.

The Wakefield Industrial Pacemaker is an economically priced, ruggedly built, heavy gauge steel luminaire that will last a long time, is quickly installed and inexpensively maintained. For more detailed information, you will want our four-page folder. Write to The F. W. Wakefield Brass Company, Vermilion, Ohio.

Wakefield Over-ALL Lighting

AT GRAYBAR, OESCO AND LEADING INDEPENDENT WHOLESALERS



miller LEXINGTON

new and most advanced for

school lighting

the fixture that gives you ***L.O.C.***

L.O.C. *(low overall cost — cost of fixture, cost of installation, cost of maintenance)* is the true cost of any lighting fixture — an important consideration in buying or specifying. MILLER LEXINGTON gives you L.O.C. And further, it gives you ideal lighting which will minimize eye strain and fatigue. The LEXINGTON embodies the latest advancements in illumination engineering. Built into it is the experience gained through 108 years of pioneering and progress in GOOD LIGHTING. It is the *latest* addition to MILLER'S complete line of luminaires for a wide range of commercial and industrial requirements.

Write or wire today — for full details of the new MILLER LEXINGTON luminaire, explaining its extremely low brightness and overall efficiency at L.O.C. (low overall cost.)

Miller field engineers and distributors are conveniently located for nation-wide service.

THE miller COMPANY MERIDEN, CONN.
SINCE 1844

ILLUMINATING DIVISION: Fluorescent, Incandescent, Mercury Lighting Equipment
HEATING PRODUCTS DIVISION: Domestic Oil Burners and Liquid Fuel Devices
ROLLING MILL DIVISION: Phosphor Bronze and Brass in Sheets, Strips and Rods

new Jefferson Series Sequence Ballast

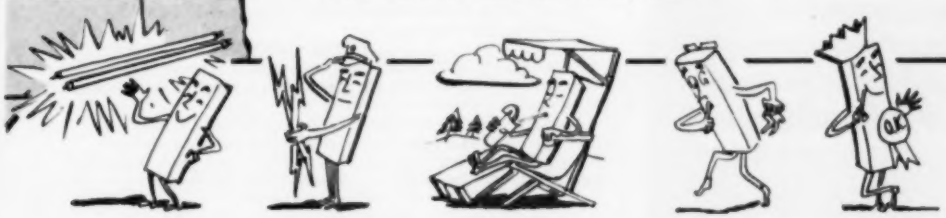
254-521 BALLAST 430 MA
118 VOLT, 60 CYCLE

for improved operation of two 48T12 fluorescent lamps in series

CERTIFIED ETL

Approved by Underwriters' Laboratories, Inc.

Everything a good ballast should have—and more, *much more* has been designed into the new Jefferson 254-521. It delivers full rated wattage with lowest loss—yet is cooler operating, quieter, lighter, and more compact. These values add up to better fixture performance—longer life and more light at less cost. POSITIVE STARTING—even at voltages as low as 106 volts—with no detrimental effect to lamp life.



MORE LIGHT PLUS LONGER LAMP LIFE
The unique Jefferson design assures maximum light output, full rated lamp life and no noticeable variations in brilliancy of the two lamps.

DELIVERS FULL RATED WATTAGE - LOWER LOSS
Maximum wattage is delivered to both lamps for utmost brilliancy. Efficiency is indicated by a wattage loss of only 21 watts.

LIVES LONGER BECAUSE IT STAYS COOL
The temperature of the Jefferson ballast remains well within A.S.A. limits—giving unlimited ballast life and better lamp performance.

SHH! NO HUM
Quiet operation is *essential* in many installations—it is certainly *desirable* in all. Jefferson's advanced design eliminates audible hum.

FULLY APPROVED
Meets all requirements of the proposed American Standard Association Test Specification C821 and supplement No. 1.

Bulletin 521-11A gives complete data.
A copy is yours on request.

JEFFERSON ELECTRIC COMPANY BELLWOOD, ILLINOIS

Now!

HEAVY-DUTY DAY-BRITE CONSTRUCTION PLUS CFI*

*COMFORT FOR INDUSTRY

These scientifically designed *aperatures* make the difference—give the ideal 10% upward component of light.

. . . the first practical answer to industry's need for comfortable lighting

Number one consideration in industrial lighting has always been rugged, durable construction . . . often at the expense of comfortable illumination. But in the past Day-Brite has consistently demonstrated that highest standards of lighting and highest standards of construction can be combined.

Now, after two years of research and study, we're ready to announce *another* great advance in industrial lighting.

To give industry even more comfortable and vision-saving illumination, Day-Brite has completely redesigned its famous Day-Line industrial line. The new CFI Day-Line is *comfort* engineered to give 10% upward light distribution and put an end to the harsh brightness contrasts and dark ceilings that hamper workers.

Now, workers can enjoy freedom from irritation and nervous fatigue due to eyestrain. Now, management can reap the benefits of more production, less work spoilage, higher employee morale and lower accident rate.

All the familiar Day-Brite features are still there, of course—die-formed heavy gauge steel construction, porcelain enameled reflectors, vibration-proof Turret sockets. And yet, CFI Day-Line prices are actually lower . . . actually mean substantial savings on industrial lighting installations.

See the Day-Brite distributor nearest you. Get the facts about this newest advance in plant lighting. Day-Brite, Inc., 5432 Bulwer Avenue, St. Louis 7, Missouri. In Canada: Amalgamated Electric Corp., Ltd., Toronto 6, Ontario.

248

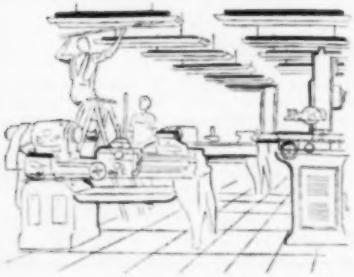
IT'S EASY TO SEE WHEN IT'S

"DECIDEDLY BETTER"
DAY-BRITE
Lighting Fixtures

HERE'S REAL BALLAST NEWS

A NEW LEAD-LAG BALLAST

- *AT SERIES BALLAST SIZES*
- *AT SERIES BALLAST ECONOMICS*
- *FOR ALL SLIMLINE LAMPS*



Lead-lag dependability in a series ballast "package" IS NEWS. This means longer lamp life, stroboscopic correction, reduced maintenance . . . PLUS the size, weight, price and power-loss advantages of a series ballast. This adds up to the *new* Westinghouse Lead-Lag ballast for all slimline lamps. Get the complete story on this new design in ballasts. Send for B-5614, Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-04316

YOU CAN BE SURE... IF IT'S

Westinghouse

LIGHTING DIVISION

Edgewater Park, Cleveland, Ohio

BENJAMIN "Magna-Flo" Systems Excel!

that's why Overall Lighting Costs are LOWER!

Because Benjamin "Magna-Flo" Systems excel by every Quality Standard—lighting, electrical and constructional—they can provide high illumination levels at low overall lighting cost. Such cost involves more than the original price of the units. Overall lighting cost also includes the costs of installation, operation, maintenance and replacement. Add them all up and see why you're ahead with "Magna-Flo" Systems (individual unit or continuous line)—because "Magna-Flo" excels by ALL QUALITY STANDARDS!

This chart gives some of the important reasons why:

"MAGNA-FLO" CUTS INSTALLATION COST	"MAGNA-FLO" CUTS MAINTENANCE COST	"MAGNA-FLO" CUTS OPERATION COST	"MAGNA-FLO" CUTS REPLACEMENT COST
wide variety of knockouts facilitate wire entrances into unit.	Porcelain Enamel reflecting surface is easy to keep clean with soap and water.	made for efficient utilization of high light output T12 Slimline lamps.	famous Benjamin "built-like-a-battleship" construction of heavy gauge steel.
complete line of sliding hangers.	exclusive "Springlox" lampholders make possible "quick-in, quick-out" lamp maintenance.	high power-factor ETL-approved ballasts for continuously-cool, efficient operation.	rigid channels and reflectors withstand toughest industrial vibration.
single, rugged channel coupling for continuous mounting.	Speedy, exclusive "Lok-Latch" reflector fasteners.	high reflection factor remains constant because genuine Porcelain Enameled reflector does not discolor or become dull with age.	96" reflectors are made in two sections, kept perfectly aligned by positive alignment clips.

FREE Bulletin AD-5705 brings you complete specifications on Benjamin "Magna-Flo" Lighting Systems—famous for "Task-Matched" Lighting Installations.
Benjamin Electric Mfg. Co., Dept. 1, Des Plaines, Ill.

D5625RB

BETTER *illumination* FOR AIRPORT RUNWAYS

KOPP *ENGINEERED LENS*

solves critical lighting problem

The value of Kopp's combined engineering and manufacturing skills is vividly demonstrated in the new bi-directional airport runway light lens, illustrated here. To overcome the shortcomings of previous runway lights, specifications were set up that could not be met by any lenses of previous design. In collaboration with Westinghouse engineers, Kopp specialists, through research, experiment and engineering development, produced a lens that fully meets or exceeds all requirements—and at a greatly reduced overall cost.

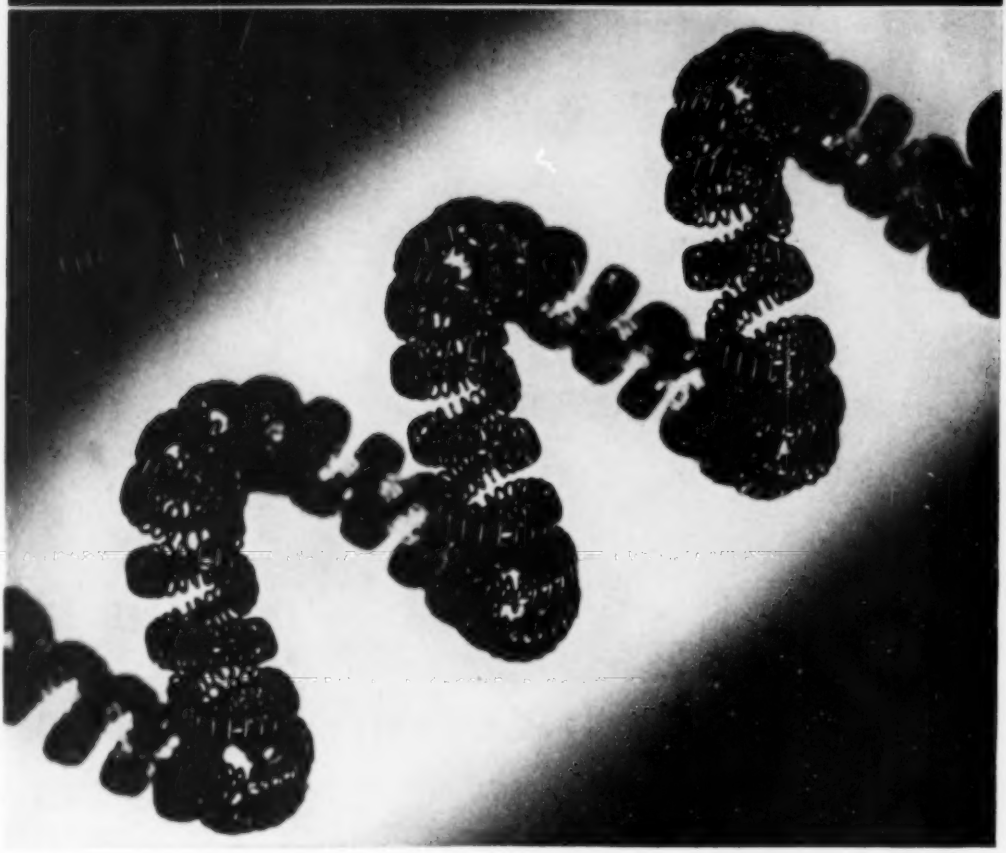
The skill, knowledge and resourcefulness displayed in developing this airport runway lens is available to anyone seeking the answer to a vexing illumination problem.

If you have a lighting problem that involves lenses or color filters for concentrating or diffusing the beam, or for transmitting any selected portion of the spectrum, Kopp engineers will be glad to help you find the lens pattern and type of glass that will give the results you want.

KOPP GLASS

KOPP GLASS, Inc.
SWISSVALE, PA.

You expect the best value from G-E fluorescent lamps



How an extra coil gives you extra light from G-E slimline lamps

A special chemical deposited on tungsten wire at each end of a fluorescent lamp helps start the stream of electrons that bring you light. When the chemical finally burns out or drops off, out goes the lamp. So in most fluorescent lamps, slimline and standard alike, wire twisted into a double coil is used to hold as much of the chemical as possible as long as possible.

But General Electric lamp scientists found a way to coil the coil again—making a *triple* coil. This triple coil holds more of the starting chemical and holds it more securely. Used in G-E slimline and other General Electric instant-start fluorescent lamps, it gives you extra light for your money because it makes the lamps last longer. This is another example of why you can *expect* the best value from G-E fluorescent lamps.

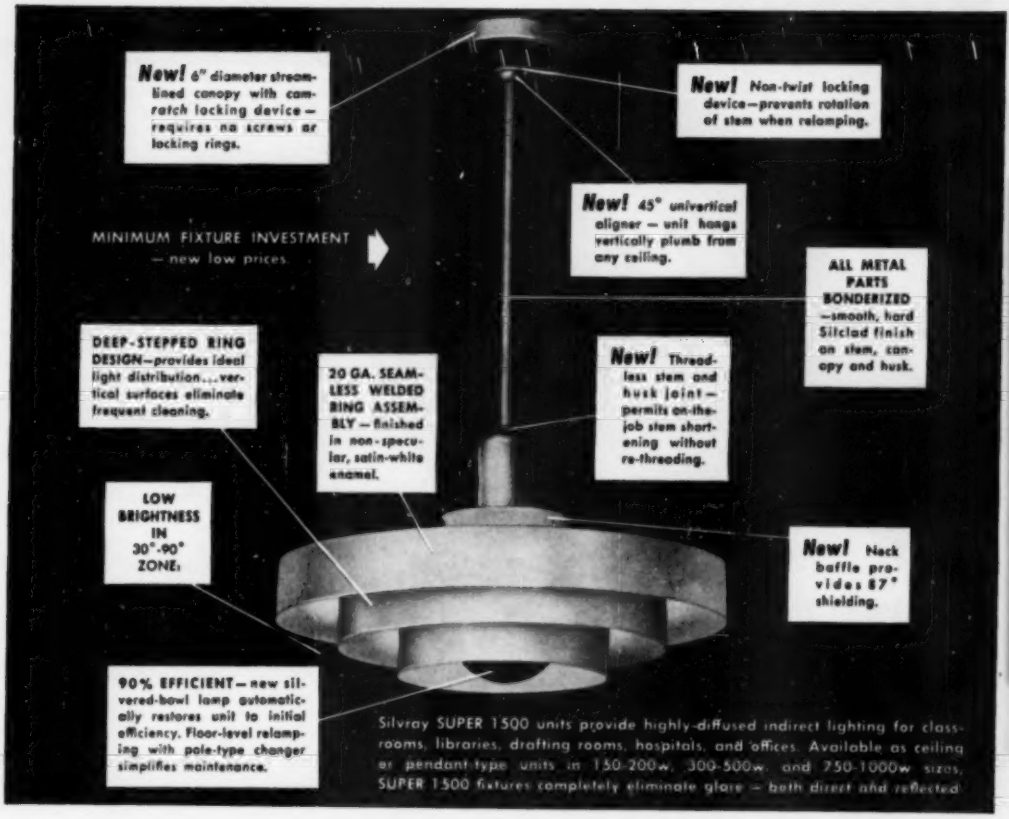
You can put your confidence in—

GENERAL ELECTRIC

COMPARE!

No other indirect, incandescent fixture offers ALL these features . . .

SILVRAY'S improved SUPER 1500 UNIT


New! 6" diameter streamlined canopy with cam-ratch locking device—requires no screws or locking rings.
New! Non-twist locking device—prevents rotation of stem when relamping.
New! 45° univertical aligner—unit hangs vertically plumb from any ceiling.
MINIMUM FIXTURE INVESTMENT —new low prices
ALL METAL PARTS BONDERIZED —smooth, hard Silclad finish on stem, canopy and husk.
DEEP-STEPPED RING DESIGN—provides ideal light distribution...vertical surfaces eliminate frequent cleaning.
20 GA. SEAMLESS WELDED RING ASSEMBLY—finished in non-specular, satin-white enamel.
New! Threadless stem and husk joint—permits on-the-job stem shortening without re-threading.
LOW BRIGHTNESS IN 30°-90° ZONE.
New! Neck baffle provides 87° shielding.
90% EFFICIENT—new silvered-bowl lamp automatically restores unit to initial efficiency. Floor-level relamping with pole-type changer simplifies maintenance.

Silvray SUPER 1500 units provide highly-diffused indirect lighting for classrooms, libraries, drafting rooms, hospitals, and offices. Available as ceiling or pendant-type units in 150-200w, 300-500w, and 750-1000w sizes. SUPER 1500 fixtures completely eliminate glare — both direct and reflected.

1927 • 1952 OUR 25TH YEAR **Silvray** *ALWAYS... the best in lighting*

Smoot-Holman, Inc. of Inglewood, Cal. — west coast licensee.

Get complete details, mail this coupon today!

SILVRAY Lighting, Inc., 104 West Main St., Bound Brook, N. J.

Gentlemen:

Please send me further information on the Silvray SUPER 1500 unit.

Name_____

Firm_____ Title_____

Address_____

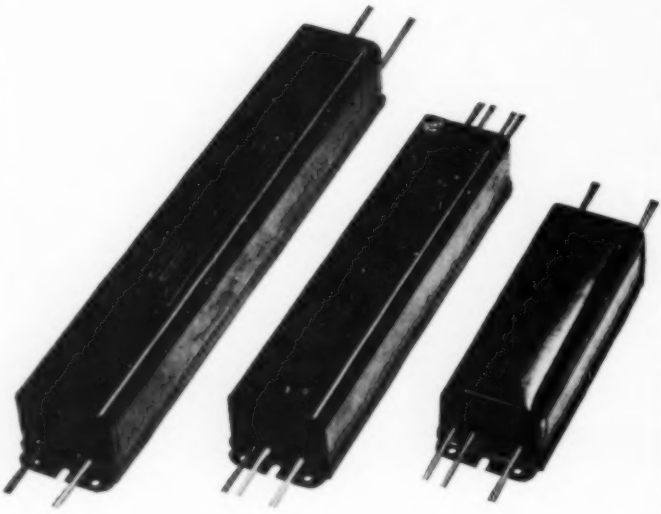
City_____ Zone____ State_____

All concentric-ring fixtures for use with silvered-bowl lamps are covered by U.S. Pat. #2,303,747 owned by Silvray Lighting, Inc.

STEP-UP the PERFORMANCE of YOUR FIXTURES with

Acme ACME Electric

BALLASTS



Let's be realistic. Fluorescent lamps need exactly the watt input for which they were designed; a 100 watt lamp will not deliver its full light output if it is limited by a ballast having an actual output of only 91.2 watts. A low watt input to lamp results in a low light output. Low pre-heat current and an excessive operating current means short lamp life. Distorted lamp current wave form leads to excessive cyclic flicker.

As a fixture manufacturer, it's your reputation at stake when you select ballasts for your product. Protect your good name with Acme Electric ballasts.

ACME ELECTRIC CORPORATION

297 WATER ST. CUBA, N. Y.

Acme ACME Electric

(*Continued from page 22A*)

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Evans, C. G., Jr., General Electric Supply Corp., Denver, Colo.
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Sams, H. G., Pueblo Electric Supply Co., Pueblo, Colo.
Shomaker, G. A., Shomaker Electric Service, Pueblo, Colo.
Stines, K. J., Earle A. Deits, Pueblo, Colo.
Sutton, A. A., 202 Don Durant Bldg., Pueblo, Colo.
Wallis, G. F., Colorado Fuel & Iron Corp., Pueblo, Colo.
Wiggons, J. G., Southwest Lighting Co., Albuquerque, N. M.

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Bueche, L. A., McDonald Electric Co. Inc., Miami, Fla.

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Clark, P. R., Southern California Edison Co., San Fernando, Calif.
Cowie, R. A., Southern California Edison Co., Redlands, Calif.
Durfee, T. H., 490 S. Brent St., Ventura, Calif.
Fairbanks, G. H., Los Angeles County Road Dept., Los Angeles, Calif.
Hawkins, L. B., Southern California Edison Co., Montebello, Calif.
Meunier, R. L., Los Angeles County Road Dept., Los Angeles, Calif.
Owings, W. B., Southern California Edison Co., Monrovia, Calif.

(*Continued on page 34A*)

Guth

the complete line of fluorescents and incandescents

When you specify GUTH Luminaires, you get the benefit of more than a half-century's experience in pioneering better lighting. We make good specialized equipment for every lighting need....all precision-planned for economical installation and maintenance.

FLUORESCENT: Commercial and Industrial; Glass diffused, Eggcrate shielded, totally indirect, luminous indirect, recessed troffers and exposed lamp types.

INCANDESCENT: Commercial and Industrial, indirect, direct and semi-indirect types; also high key reflectors, exit and utility lighting units.

"ALL-SQUARE" ...for recessing. One-piece die-cast frame. Light-leakproof. Widespread or concentrating lens...sizes 6½" sq., 8" sq. & 12" sq. PRE-WIRED. Removable top, and drop hinge bottom for servicing from above or below. Catalog 49.

▲ "ALL-SQUARE"

SEELUX ...totally indirect open bottom Luminaire for for Silver Bowl Lamps, with modern ALZAK concentric louvres; for stem suspension or close mounting. Bulletin 864.

▲ SEELUX*

ARISTOLITE ...hinged glass panels swing open for easy cleaning from floor with handy servicing tool. Also with center Eggcrate louvres. For 2, 3 or 4 40-watt or 2 or 4 4-ft. SLIMLINE lamps; ceiling or suspension, unit or continuous mounting. Write for Bulletins 812 and 820.

▲ ARISTOLITE*

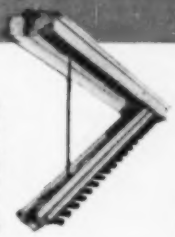
NEW FUTURLITER ...with GUTH GRATELITE* the 48" long plastic louvre with 45 x 45 cut off for efficient vertical illumination and low brightness diffusion at angles above 45°. GRATELITE is made in sizes up to 48" long. Easy to install on single fixtures or complete ceilings. Available in opaque or transparent densities. Send for information.

*Patent Pending

▲ NEW FUTURLITER*

TRUCOLITE ...versatile, highly efficient, semi-direct type; can be used open, with Eggcrate louvres or diffusing glass bottom. For 2, 3 and 4 40-watt lamps...also 2 and 4 4-ft. or 8-ft. SLIMLINE lamps. Ceiling or suspension, unit or continuous mounting. Bulletins 814 and 852.

▲ TRUCOLITE*



GUTHLITE ... the revolutionary "Jacknife" Hinge Luminaire that swings down for easy relamping or cleaning right from the floor! For 2 40- or 2 85-watt or 2 4-ft. SLIMLINE lamps; ceiling or suspension, unit or continuous mounting. Simplest fixture to install. Bulletin 845.

▲ GUTHLITE*

WYTE-LINER ...white inside and outside (takes gloom off ceiling). AIRFLOW channel for longer ballast life. Reflectors 300* Permalux or Porcelain Enamel. Made in 2 and 3 40-watt, 2 85-watt, and 4- and 8-ft. SLIMLINE lamps. Easy to install and clean. Catalog 48.

▲ WYTE-LINER

HY-LITERS ...recessed and surface types for PAR 38. Adjustable 45° from vertical in all directions. Can be used as individual units, or in conjunction with our fluorescent types. Bulletin 834.

▲ HY-LITERS

"LITE-BLOX" RECESSED TROFFERS ... for 1, 2, 3 or 4 lamps: 20-, 40-, 85-watt, or 4-ft., 6-ft., or 8-ft. SLIMLINE. Exclusive end KO's provide exact 48.0"; modular design for unlimited patterns. Wide variety of shielding and diffusing glass panels available; also ALZAK reflectors if desired. Bulletin 869.

▲ "LITE-BLOX" RECESSED TROFFERS

GUTH 4-FT. SLIMLINE available in every GUTH fluorescent fixture

- no starters or starter troubles!
- easy to handle Single-Pin lamps!
- light in two steps almost instantly!

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WAR on WASTE
by
Engineered Maintenance
A COMPLETE FILE OF WORKING DATA FOR APPLYING
1. CHAMPION'S PLANNED CLEANING PROGRAM
2. CHAMPION'S GROUP REPLACEMENT PLAN [FOR FLUORESCENT LAMPS]
3. CHAMPION'S GROUP REPLACEMENT PLAN [FOR INCANDESCENT LAMPS]
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means THE BEST

— *if you have any interest in lighting efficiency and economy*

— *and if you'd like the answers to questions such as these:*

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HOW can I duck 83% of my lamp burnouts?

WHEN does group replacement pay off?

WHY and *how* can I replace six lamps for what it now costs me to replace one?

YOURS WITHOUT COST OR OBLIGATION

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Street .....

City ..... *Zone* ..... *State* .....

(Continued from page 32A)

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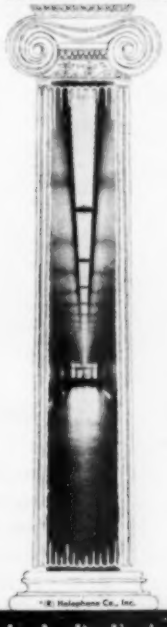
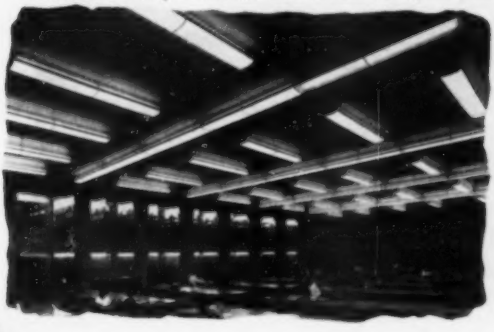


The Greek sense of proportion and the contemporary sense of directness and simplicity have been combined into the design of Sunbeam luminaires for one of the foremost universities on the west coast. Fully enclosed for minimum maintenance, over 470 Sunbeam #H8080 series were installed in the Law Building. Notwithstanding the 16-foot ceiling in the library, these units, equipped with Controlens® elements, provide more than 50 footcandles at desk level. Nearly 1000 glass and louver shielded #L1710 series fixtures were installed in the Arts Building. Note the long, perfectly straight, continuous run of Sunbeam's new corridor units, the #L1711.



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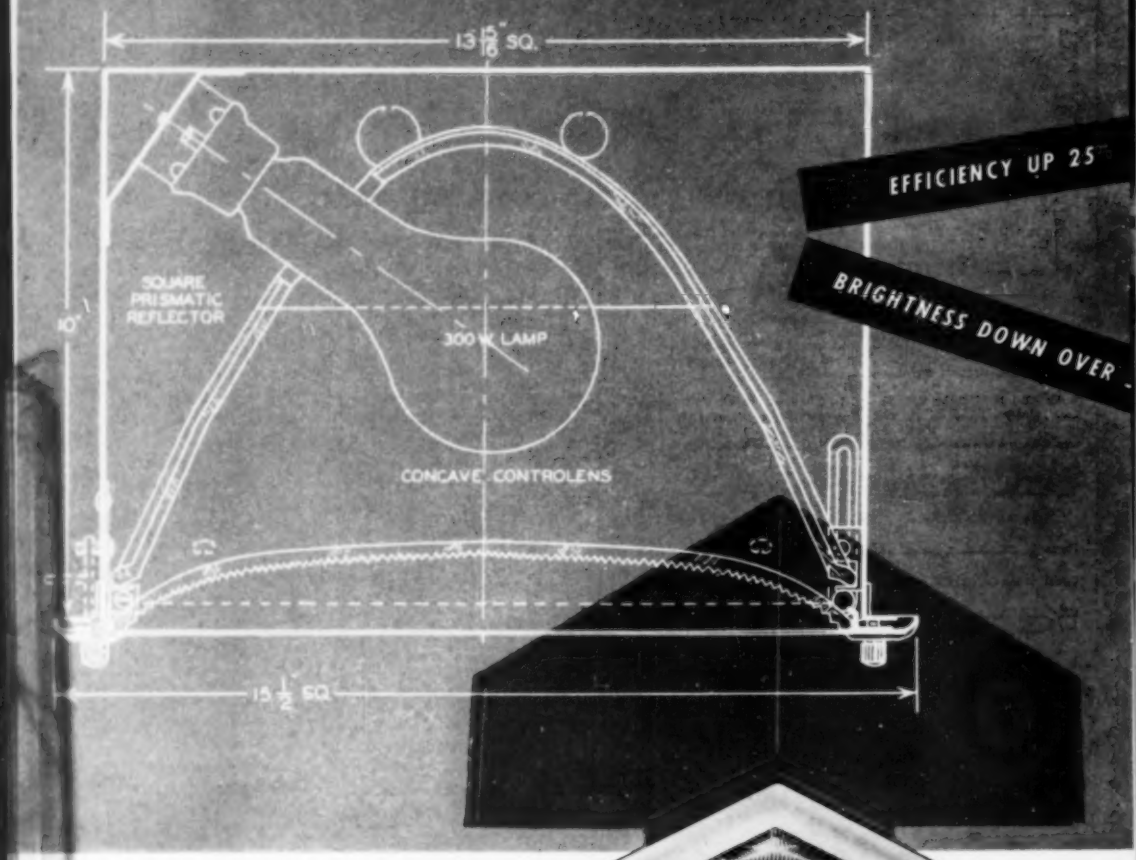
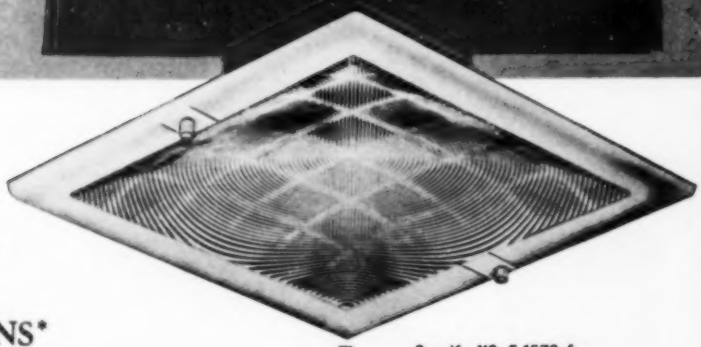
HOLOPHANE DEVELOPS AN ENTIRELY NEW CONCEPT IN LIGHTIN





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- **HIGHER EFFICIENCY... Stepped up 25%**
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INDEX TO ADVERTISERS
July 1952

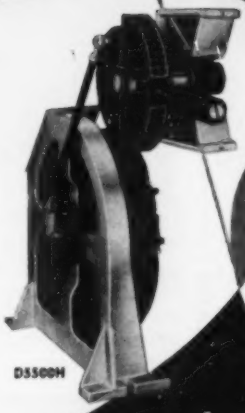
Acme Electric Corp.	32A
Advance Transformer Co.	13A
Benjamin Electric Mfg. Co.	28A
Certified Ballast Manufacturers	Inside Back Cover
Champion Lamp Works	34A
Curtis Lighting Inc.	4A
Day-Brite Lighting Inc.	26A
Fluorescent Fixtures of Calif.	19A
General Electric Co., Lamp	30A
Edwin F. Guth Co.	33A
Holophane Co. Inc.	36A
Jefferson Electric Co.	25A
Kopp Glass Inc.	29A
Leader Electric Co.	20A
Litecontrol Corp.	2A
Miller Co.	24A
Pittsburgh Reflector Co.	Inside Front Cover
Rohm & Haas Co.	17A
Silvray Lighting Inc.	31A
Sola Electric Co.	38A
Solar Light Manufacturing Co.	35A
Sunbeam Lighting Co.	35A
Superior Electric Co.	37A
F. W. Wakefield Brass Co.	23A
Westinghouse Electric Corp., Lamps	Back Cover
Westinghouse Electric Corp., Lighting	1A, 27A
J. A. Wilson Lighting & Display Inc.	14A

Announcing

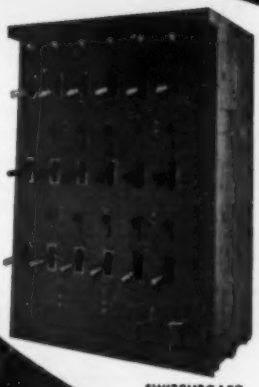
a new line of

INTERLOCKING POWERSTAT

light dimming equipment



D5500H



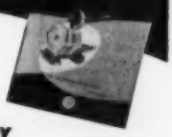
SWITCHBOARD

for SWITCHBOARD INSTALLATIONS

A new line of 5500 watt INTERLOCKING POWERSTAT Dimmers has been developed for use as switchboard components. Furnished as individual units or in angle iron frames, these interlocking assemblies are designed for mounting on 3 inch centers in any position in back of the shaft handle. They are driven with a simple, positive rod connection from the drum handle to a planetary gear assembly on the dimmer. Ball-bearing mounts assure quiet, smooth, free operation. The dimmers are removable from the frame, and the brush-contact can be serviced without taking the POWERSTAT from the frame.

For simplicity of wiring, the terminals can be located at the front or back. A tapered coil winding means linear dimming from full-on to black-out.

The D5500H is rated 120 volts, 50/60 cycles, single phase input, 0-5500 watts output.



WRITE TODAY FOR BULLETIN D4521 DESCRIBING THE COMPLETE LINE OF INTERLOCKING POWERSTAT DIMMERS

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☐ Send Bulletin D4521
☐ Send information on complete POWERSTAT Dimmer line
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The New SOLA Dynatran* Lead-Lag Fluorescent Ballast

SURPASSES
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SPECIFICATIONS

Yes, now it's a fact, Sola Dynatran* Ballasts let you have your cake and eat it too! These new ballasts give you the advantages of lead-lag operation (of instant-start lamps) with the small size, light weight, efficiency and economy of Sequenstart Ballasts.

Sola Dynatran* Ballasts are presently available for lead-lag operation of two 30T12 and 48T12 instant-start fluorescent lamps. They are the *only* lead-lag ballasts made with ventilated capacitor compartments for long capacitor life and, consequently, *long ballast life*. Dynatran* Ballasts are *premium performance* units at moderate cost.

COMPARISON OF SOLA DYNATRAN* BALLAST WITH A.S.A. C82.1 SPECIFICATIONS.

	A.S.A. C82.1 MINIMUM SPEC.	SOLA No. 624-408 DYNATRAN*	% DYNATRAN* SUPERIORITY
1. Open Circuit Volts	385 v @ 90% Nom. Volts.† Minimum	410 volts, average	6.5%
2. Starting Current	100ma @ 90% Nom. Volts.† minimum thru 2750 ohms	135 ma. average	35.0%
3. Wave Shape (Ratio peak / RMS)	1.95 @ Nom. Volts.† maximum	1.48, average lead and lag lamps	19.5%
4. Temperature Rise on Winding at Normal operation	65°C @ Nominal Volts maximum	47.7°C average of all coils	26.6%
5. Temperature rise on Capacitor at Normal operation	30°C @ Nominal Volts maximum	17°C average of all coils	43.3%

† Nominal Voltage, 118 volts; 90% Nominal Voltage, 106 volts.
Figures reported from test made on Sola Dynatran* Ballast Catalog No. 624-408 by E.T.L. on a 40 Watt bi-pin instant-start lamp.

COMPARE THESE Sola Dynatran* No. 624-408 FIGURES WITH ORDINARY LEAD-LAG BALLASTS

- Watts loss, 24.0
- Efficiency, 77%
- Weight, Approx. 9 lbs.
- Case length, 10½"
- Overall width, 3¼"
- Overall height, 2⅝"

A complete specification bulletin is now being prepared. It will be sent to you as soon as it is off the press. Please write on your letterhead for Dynatran* Bulletin C-PFL-165.

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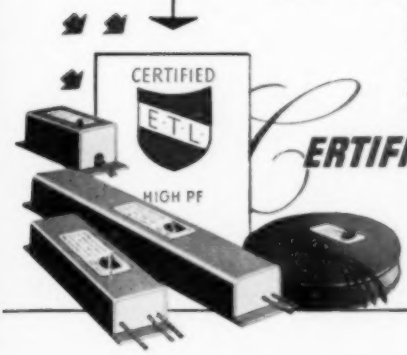
CERTIFIED BALLASTS are tested by Electrical Testing Laboratories, Inc., which certifies they meet the precise specifications that assure efficient operation.

You can tell a ***CERTIFIED BALLAST*** *by the shield.*



• Complete information on the types of CERTIFIED BALLASTS available from each participating manufacturer may be obtained from Electrical Testing Laboratories, Inc., East End Avenue at 79th Street, New York, New York.

Participation in the CERTIFIED BALLAST program is open to any manufacturer who complies with the requirements of CERTIFIED BALLAST MANUFACTURERS.

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Makers of Certified Ballasts for Fluorescent Lighting

2116 KEITH BLDG., CLEVELAND 15, OHIO

Rare gases up light and efficiency of new lamp

A Westinghouse Research Engineer is shown operating the rare gas apparatus in which the new krypton and argon gas fill were developed. As a result of krypton-argon, the new Westinghouse 90-watt fluorescent gives 6% more light for only 2% more current.

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The new 90-watt will fit present 85-watt fixtures. It will hold the level of light above your minimum foot candle value longer. It'll reduce annual cost of light. Contact your nearest Westinghouse Lamp Sales Office for more information.

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